Draft Comparative Environmental Evaluation of Alternatives for Handling Low-Level Radioactive Waste Spent Ion Exchange Resins from Commercial Nuclear Power Plants

Draft Report for Comment

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COMPARATIVE ENVIRONMENTAL EVALUATION OF ALTERNATIVES FOR HANDLING LOW-LEVEL RADIOACTIVE WASTE SPENT ION EXCHANGE RESINS FROM COMMERCIAL NUCLEAR POWER PLANTS

CONTENTS

FIGURES

TABLES

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EXECUTIVE SUMMARY

INTRODUCTION AND PURPOSE

This report presents a comparative environmental evaluation of six alternatives for handling low-level radioactive waste (LLRW) spent ion exchange resins (IERs) from commercial nuclear power plants (NPPs). An NPP is defined as a thermal electric power generating station in which the heat source is one or more nuclear power reactors. Currently, there are 104 operating nuclear power reactors located at 65 commercial NPPs in the United States. The evaluation has been conducted consistent with Option 2 in the U.S. Nuclear Regulatory Commission (NRC) staff's paper for the Commission, SECY-10-0043, "Blending of Low-Level Radioactive Waste," April 7, 2010, which identified policy, safety, and regulatory issues associated with LLRW blending, provided options for an NRC blending position, and made a recommendation for a future blending policy. Option 2 proposed that the staff revise the Commission position on blending to be risk-informed and performance based. Option 2 was approved by the Commission in the October 13, 2010, Staff Requirements Memorandum, SRM-SECY-10-0043, "Staff Requirements - SECY-10-0043 - Blending of Low-Level Radioactive Waste."

Additionally, in consideration of stakeholder concerns expressed regarding potential environmental impacts associated with the blending of certain LLRW, as documented in the NRC's Official Transcript of its January 14, 2010, "Public Meeting on Blending of Low-Level Radioactive Waste," in SECY-10-0043, Option 2, the staff also proposed that "…disposal of blended ion exchange resins from a central processing facility would be compared to direct disposal of the resins, onsite storage of certain wastes when disposal is not possible and further volume reduction of the Class B and C concentration resins." The purpose of this report is to address this comparison of alternatives in the form of a comparative environmental evaluation of these IER waste handling options. The six alternatives evaluated in this report include the four identified by the NRC staff in SECY-10-0043, plus two additional alternatives that represent variations on the disposal of blended ion exchange resins from a central processing facility and volume reduction of the Class B and C concentration resins alternatives.

In the comparative environmental evaluation, the six alternatives are described and potential environmental impacts of the alternatives are: (1) identified for a range of resource or impact areas (e.g., air quality, ecological resources, public and occupational health, transportation, waste management, water resources); and (2) compared in terms of their relative potential effects on human health and the environment. For reasons discussed in the report, the six alternatives are generic and not location-specific, in that they generally are not intended to represent any actual actions or facilities; and the comparative environmental evaluation of these alternatives is largely qualitative, with measures of potential environmental impacts expressed as characteristics as opposed to specific quantities or numerical magnitudes. An exception is that potential transportation impacts are assessed both quantitatively (based on numerically calculated or modeled consequences) and qualitatively. Potential radiological impacts during transportation of spent IERs on public roadways were estimated using the RADTRAN 6 model, which is the nationally accepted, standard computer program for calculating the risks of transporting radioactive materials.

Furthermore, the evaluation is based on a number of conservative, often bounding assumptions regarding the alternatives and various aspects of the analysis. This approach is consistent with the assessment of generic, non-location-specific alternatives, for which exact data and information would not be available. Consequently, the staff used its professional knowledge, experience, and judgment to establish reasonable technical considerations, estimations, and approximations with regard to how the alternatives were described, would be implemented, and would potentially affect human health and the environment. The staff also took care not to underestimate the potential environmental effects and instead worked to bound the possible range of outcomes in most cases. Thus, the impacts of the six alternatives, if implemented in actual practice, would be expected to be of somewhat lesser magnitude than described in this report.

IERs are small, bead-like materials used by commercial NPPs to capture radioactive contaminants dissolved in water used in plant operations. Over time, the IERs lose their ability to remove the contaminants from the water and the resins become “spent” and must be removed and replaced. The average total volume of spent IERs generated annually by commercial NPPs in the United States is about 2568 cubic meters (90,620 cubic feet) (see Table 2 in Section 2.1.3 of this report). The NRC defines three classes of LLRW—Class A, Class B, and Class C—in its regulations in Title 10 of the *Code of Federal Regulations* (10 CFR) 61.55. Of the three classes, Class A LLRW is the least hazardous and Class C is the most hazardous. Disposal facilities for LLRW are licensed to accept one or more of these classes of waste. Waste that exceeds the Class C limits is not generally acceptable for near-surface disposal. Licensees do not allow IERs to exceed the Class C limits, and waste at greater-than-Class C limits is not considered in this report. Spent IERs are managed as LLRW, and are classified as Class A, Class B, or Class C LLRW when shipped for disposal, depending on the radioactivity of the radionuclides present.

Currently, there are four licensed, operating LLRW disposal facilities in the United States. One of these facilities is licensed to dispose of, and can accept, Class A LLRW from all 50 states. The other three facilities are licensed to dispose of Class A, B, and C LLRW, but can accept these wastes only from a limited number of states; however, one of these three facilities recently received approval to accept LLRW from individual generators in additional states, but only on a case-by-case basis and subject to annual activity and volume limits. As a result, all U.S. commercial NPPs (which currently include 104 operating nuclear reactors at 65 NPP locations) can dispose of their Class A LLRW spent IERs, but more than 40 of the 65 operating NPPs have no access, or only limited access, to a disposal facility for their Class B and C spent IERs at this time. Given this situation, LLRW processing and waste disposal companies are exploring alternatives for managing Class B and C concentration spent IERs.[1]

One of these alternatives is to use a centralized processing facility to blend small volumes of higher-activity Class B and C concentration spent IERs with larger volumes of low activity Class A concentration spent IERs to produce Class A waste. The potential environmental impacts of this alternative, as compared to the potential impacts of the other alternatives, are presented in this report.

SCOPE OF THE EVALUATION

The six alternatives evaluated in this report are:

- Alternative 1A—Direct disposal of blended Class A, B, and C spent IER LLRW from a central processing facility where mechanical mixing would be used to blend the spent IERs to produce Class A waste
- Alternative 1B—Direct disposal of blended Class A, B, and C spent IER LLRW from a central processing facility where thermal processing would be used to blend the spent IERs to produce Class A waste

Alternatives 1A and 1B represent variations on the "disposal of blended ion exchange resins from a central processing facility" alternative in SECY-10-0043, Option 2. Both of these alternatives are included in this evaluation because both mechanical mixing and thermal processing are assumed for this evaluation to be available technologies for the blending of Class A, B, and C concentration spent IERs.

- Alternative 2—Direct disposal of the Class A, B, and C spent IER LLRW (without blending)
- Alternative 3—Direct disposal of the Class A spent IERs, with long-term (20-year) onsite storage of the Class B and C concentration spent IERs at the NPPs (including construction (expansion) of the waste storage facilities at the NPPs), followed by disposal of the Class B and C spent IERs at the end of the long-term storage period
- Alternative 4A—Direct disposal of the Class A spent IERs, with volume reduction (by thermal processing) of the Class B and C concentration spent IERs, followed by long-term (20-year) storage of the volume-reduced Class B and C concentration spent IERs (including construction of a storage facility at an existing LLRW disposal site), and then disposal at the end of the long-term storage period

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[1] Throughout this report, spent IERs that are not yet being shipped for disposal are referred to as Class A, B, or C *concentration* spent IERs, rather than as Class A, B, or C *waste*. The Class A, B, and C designations are related to the hazards that the waste presents to an inadvertent human intruder after closure of a LLRW disposal facility, and are not related to the hazards at intermediate points in handling. NRC regulations in 10 CFR 20 Appendix G do not require LLRW to be classified until it is shipped for disposal.

- Alternative 4B—Direct disposal of the Class A spent IERs, with volume reduction (by thermal processing) of the Class B and C concentration spent IERs, then disposal of the volume-reduced Class B and C spent IERs.

Alternatives 4A and 4B represent variations on the “further volume reduction of the Class B and C concentration resins” alternative in SECY-10-0043, Option 2. Both of these alternatives are included in this evaluation because a disposal option for Class B and C wastes from all 50 states may or may not be available in the near-term, and long-term storage of these wastes would be necessary if a disposal facility is not immediately available (as in Alternative 4A).

Detailed descriptions of these alternatives and the assumptions used in this evaluation are included in the full report. For example, the baseline for this evaluation is current land use. This means that, with the exception of the construction of the long-term waste storage facilities considered in Alternatives 3 and 4A, this evaluation assumes that no new IER storage, handling, processing, and disposal facilities will be constructed and, therefore, this evaluation does not revisit the impacts of construction of any of these facilities. In addition, the evaluation assumes that these facilities operate under licenses from the NRC or an Agreement State[2], and that all activities conducted in the alternatives would be in compliance with all applicable Federal, State, and local legal and regulatory requirements.

Additionally, each alternative is considered individually in the evaluation (i.e., each alternative is assumed to be implemented at the exclusion of all the other alternatives). There is no mix of alternatives, and all spent IERs generated at all 65 NPPs are assumed to be managed under each alternative. It is recognized that Agreement State requirements or other factors could prevent some NPPs from using some alternatives, and that in actual practice all spent IERs generated at all 65 NPPs would not be managed under any single alternative. Therefore, the assumption that all spent IERs are managed under each alternative results in conservative estimates of the potential impacts of each alternative.

The assumptions used in this evaluation, such as those described above, are reasonable and consistent with SECY-10-0043, Option 2, which established the basis for this comparative environmental evaluation. These assumptions are also necessary to place all six alternatives on a relatively equal footing, which helps avoid bias in the results of the comparative evaluation.

The assessment of potential environmental effects of the six alternatives evaluated the following resource or impact areas: air quality, ecological resources, historic and cultural resources, noise, public and occupational health, soil, transportation, waste management, and water resources. Other resource and impact areas were eliminated from detailed consideration for reasons discussed in Section 3.3. In addition, to the extent practicable, the evaluation of potential environmental impacts identifies and accounts for generally accepted impact mitigation

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[2] Agreement States are states that have been granted certain NRC regulatory authority under the Atomic Energy Act of 1954, as amended (AEA). Section 274 of the AEA provides a statutory basis under which the NRC relinquishes to the Agreement States portions of its regulatory authority to license and regulate byproduct materials (radioisotopes), source materials (uranium and thorium), and certain quantities of special nuclear materials.

measures in each resource or impact area that would typically be employed in general industry practice. In accordance with the standard of significance that has been established by the NRC for assessing environmental impacts, using the standards of the Council on Environmental Quality's regulations in 40 CFR 1508.27 as a basis, each impact for each alternative was assigned one of the following three significance levels: SMALL, MODERATE, or LARGE.

SUMMARY OF COMPARATIVE ENVIRONMENTAL EVALUATION

The evaluation concludes that the potential environmental impacts of all six alternatives in all resource and impact areas would be SMALL, with the exception of potential impacts on historic and cultural resources from construction of long-term waste storage facilities in Alternatives 3 and 4A, which could be SMALL to MODERATE. As summarized below for each resource and impact area, there are several reasons why these potential environmental impacts would be mostly SMALL.

Air Quality

Nearly all of the radiological and non-radiological air emissions would come from the blending (mechanical mixing, thermal processing) and volume reduction facilities in Alternatives 1A, 1B, 4A, and 4B. Note that among Alternatives 1A, 1B, 4A, and 4B, air emissions from the ambient temperature mechanical mixing (blending) process in Alternative 1A could be less than those from Alternative 1B (blending using thermal processing) and Alternatives 4A and 4B (volume reduction by thermal processing), which would involve treatment of spent IERs at elevated temperatures (800˚C) with resulting increased volatilization of constituents. However, emission controls (e.g., off-gas filtration equipment in the case of the thermal processing options) would be employed at these facilities as necessary to maintain compliance with applicable air quality regulations and keep emissions within regulatory limits (e.g., under the National Emission Standards for Hazardous Air Pollutants (NESHAPs) and National Ambient air Quality Standards (NAAQS)). Non-radiological air emissions from equipment usage and fugitive dust generation during spent IER handling and disposal, and during construction of relatively small, long-term spent IER storage facilities in Alternatives 3 and 4A, would be temporary and intermittent in nature and would also be subject to air quality regulations. Non-radiological emissions would also be minimized and controlled using emissions controls, best management practices (BMPs), and other mitigation measures as necessary.

Ecological Resources

The analysis assumes that existing NPPs and spent IER processing and disposal facilities would operate within existing facility footprints. There would be minimal or no additional ground disturbance or other activities during spent IER handling and processing activities, and none during spent IER transport. Therefore, any impacts on wildlife and plants from these operations would be minimal. Any air emissions and wastewater discharges would be within regulatory limits and noise mitigation measures would keep noise levels and any associated ecological impacts to a minimum. Potential impacts from construction of long-term spent IER storage facilities in Alternatives 3 and 4A would be SMALL due to the very small sizes of these facilities;

and would be avoided, minimized, or mitigated where possible, based on threatened and endangered species surveys and consultations with the U.S. Fish and Wildlife Service and corresponding State agencies.

Historic and Cultural Resources

The existing NPPs and waste processing and disposal facilities would be operating within existing facility footprints. There would be minimal or no additional ground disturbance during spent IER handling, processing, and disposal, and none during spent IER transport. Therefore, no destruction of, or other adverse effects on, historic or cultural resources would be expected as a result of these activities. Construction of long-term spent IER storage facilities in Alternatives 3 and 4A could possibly encounter and destroy, or otherwise adversely affect, resources determined eligible for listing in the National Register of Historic Places (i.e., historic properties). However, the footprints of these storage facilities would be relatively small, and conduct of cultural resource inventories and surveys, consultation with State Historic Preservation Officers and Tribal Historic Preservation Officers, and implementation of appropriate impact avoidance, minimization, or mitigation measures would keep the impacts to these resources at SMALL to MODERATE levels.

Noise

Noise resulting from spent IER handling, processing, storage, and disposal would occur at existing, licensed facilities in compliance with applicable noise regulations; and noise mitigation measures would be employed as necessary. Noise impacts during construction of long-term spent IER storage facilities in Alternatives 3 and 4A would be temporary and intermittent in nature, and could be minimized in populated areas, if necessary, through suitable scheduling of construction activities or other measures.

Public and Occupational Health

Worker activities for handling, processing, storage, and disposal of spent IERs must comply with NRC, Agreement State, Occupational Health and Safety Administration (OSHA), and other worker protection requirements and standard operating procedures, as applicable (e.g., as low as reasonably achievable (ALARA)). Compliance with these regulations would limit any radiological and non-radiological occupational exposures to acceptable levels. The nature of facility operations, facility access limitations, applicable air quality, noise, water quality, and waste management regulatory requirements (e.g., air quality standards under NESHAPs and NAAQS, water quality requirements under the National Pollutant Discharge Elimination System (NPDES)), emissions control and mitigation measures at the NPPs and waste processing and disposal facilities, and implementation of maintenance and monitoring programs at long-term spent IER storage facilities would result in minimal or no exposure of members of the public to radiological and non-radiological constituents.

Soil

Except for construction of long-term spent IER storage facilities at the NPPs in Alternative 3 and at the waste disposal site in Alternative 4A, essentially no activities would take place during spent IER handling and processing at the existing facilities, and during spent IER transport, that would result in soil disturbance or contamination, other than accidental spills that would be immediately addressed in accordance with spill prevention, control, and countermeasures (SPCC) plans. Construction of long-term spent IER storage facilities at the NPPs and the waste disposal site in Alternatives 3 and 4A, respectively, and waste disposal activities, would involve application of BMPs (e.g., earth berms, dikes, sediment fences) to reduce soil erosion and implementation of SPCC plans for cleanup of accidental spills.

Transportation

A brief explanation of some of the assumptions, methodologies, and terminology used in the transportation analysis in this report is necessary to understand the results summarized below. These results are described in detail in Appendix A of the report.

Spent IERs would be transported to waste processing and disposal facilities on public roadways in special, certified shipping casks (typically Type A or Type B certified casks) loaded on tractor-trailer trucks. This evaluation assumed that lower-activity Class A concentration spent IERs would be shipped in Type A casks, and higher-activity Class B and C concentration IERs would be shipped in the more robust Type B casks. Depending on the alternative, there would be shipments of full casks of spent IERs from the NPPs to waste processing (blending, volume reduction) facilities or waste disposal facilities and from waste processing facilities to waste disposal facilities, and return shipments of empty casks from waste processing and disposal facilities.

Three categories of potential transportation impacts were assessed in this evaluation, which represent the range of reasonable impacts to the public from the transportation of spent IERs (full and empty casks): (1) impacts on local and national traffic; (2) radiological impacts of routine transportation[3] on individuals and populations; and (3) non-radiological and radiological impacts of transportation accidents. Note that exposures of “radiation workers” (e.g., truck crews, package handlers, and inspectors) are not considered in this analysis because these workers are specially trained in, and knowledgeable of, necessary radiation safety requirements and procedures, and are monitored and have radiation exposure limits stipulated by NRC regulation in 10 CFR 20.1201.

Radiological impacts to individual human receptors are expressed in terms of radiation dose, or simply dose, which is a measure of the biological damage to an individual from ionizing radiation measured in units of millisieverts (mSv) or millirem (mrem). Individual receptors are persons at

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[3] Routine transportation takes place without incident. A transportation incident is any event that interferes with transportation between origin and destination. A transportation accident is an event that results in death, injury, or enough damage to an involved vehicle that the vehicle cannot move under its own power. All accidents are incidents.

various locations along transportation routes traveled by trucks carrying radioactive materials (e.g., spent IERs from NPPs). Radiological impacts to populations are expressed in terms of the "collective dose" (expressed in units of person-mSv[4]), by integrating the average radiation dose over the area occupied by the population (using the RADTRAN 6 model). Populations are groups of residents along the transportation routes. For this evaluation, individual and collective doses were calculated on an annual basis. Radiological impacts to individuals and populations were also assessed in terms of latent cancer fatalities (LCFs), which are the expected number of additional cancer fatalities that may occur during the lifetime of individuals because of (or latent to) an exposure to ionizing radiation. LCF values are derived from the dose and collective dose results.[5] Non-radiological transportation impacts assessed in this evaluation are associated with the effects of spent IER transport on local and national traffic volumes and associated traffic congestion, air quality, noise levels, and road surface wear, and on transportation accident (e.g., vehicle collisions) frequencies and associated traffic fatalities.

As discussed below, for the three categories of potential transportation impacts assessed in this evaluation, the quantitatively estimated, potential non-radiological and radiological impacts to members of the public from the shipment of spent IERs and empty casks would be small to negligible in magnitude.

- Local and National Traffic Impacts. On a local level, the numbers of trucks transporting spent IERs or empty casks on local roads near the waste processing or disposal facilities were estimated to range from about one truck per 8-hour operating day near the spent IER processing (volume reduction) facilities in Alternatives 4A and 4B, to about one truck per operating hour near the spent IER processing (blending) facilities in Alternatives 1A and 1B. This range in the numbers of trucks traveling on local roads represents very small additions to local traffic in the vicinities of industrial sites. On a national level, total annual spent IER freight shipments (full and empty casks) would constitute approximately 0.0002 to 0.0005 percent (depending on the alternative) of the total annual U.S. freight weight carried by tractor-trailer trucks. These percentages would be even smaller (negligible) as compared to total annual national vehicle traffic (tractor-trailer trucks plus all other vehicles). Corresponding to these small local and national traffic impacts, there would be SMALL impacts on associated traffic congestion, air quality, noise levels, and road surface wear.

- Radiological Impacts of Routine Transportation. For individuals, the highest estimated doses (as calculated using RADTRAN 6) and corresponding LCFs would be to the

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[4] Person-mSv is a unit of dose that represents an individual dose integrated over an area that is occupied by a population. It can be thought of as an average individual dose multiplied by the number of people over which it is averaged.

[5] To put the annual doses to individuals in perspective, the annual doses are compared in this report with the average annual U.S. background dose of 3.6 mSv/year (360 mrem/year), as a percentage of the background dose. For populations, the annual collective dose is compared to 3.6 mSv multiplied by the affected population. The use of the annual U.S. background radiation level assumes that the background level would be the same for all receptors. Also, the calculated latent cancer fatalities (LCFs) are expressed as a fraction (percentage) of the American Cancer Society's 2010 total estimated cancer fatalities in the U.S. of 569,495.

"maximally exposed individual", or MEI[6], and to residents near truck rest and refueling stops, although these would all be low. However, the radiological impacts of the alternatives would be similar to each other. The MEI dose from moving trucks carrying all spent IER shipments annually in the six alternatives would range from approximately 0.03 to 0.07 percent of the average annual U.S. background radiation dose; and the corresponding LCFs would be negligible, ranging from about 1 x 10-11 to 3 x 10-11 percent of 2010 total estimated U.S. cancer fatalities. For an average resident near a truck stop, the dose from trucks carrying all spent IER shipments annually would range from approximately 0.050 to 0.12 percent of the background dose, and the corresponding LCFs would range from 2 x 10-11 to 5 x 10-11 percent of 2010 estimated cancer fatalities. Radiation doses and LCFs to all other types of individual receptors considered in the analysis—i.e., average persons along transportation routes in rural, suburban, and urban settings—would be orders of magnitude lower.

For populations along the transportation routes and near truck rest and refueling stops, the maximum annual collective population doses and LCFs from moving and stationary trucks, respectively, from all annual spent IER shipments for each of the six alternatives, would also be similar. Collective population doses from moving trucks would range from about 6 x 10^{-6} to 7 x 10^{-5} percent of the U.S. average annual background radiation dose; and corresponding LCFs would be negligible, ranging from about 1 x 10^{-10} to 3 x 10^{-9} percent of 2010 total estimated U.S. cancer fatalities. For trucks at rest and refueling stops, collective population doses from stationary trucks would range from about 0.03 to 0.2 percent of background; and corresponding LCFs would be negligible, ranging from about 1 x 10^{-8} to 4 x 10^{-8} percent of 2010 estimated cancer fatalities.

Note that in actual practice, impacts to both individuals and populations would be lower than estimated because not all residents would be at the same locations for an entire year and not all trucks carrying spent IERs would stop at the same rest and refueling stops.

- Non-radiological and Radiological Impacts of Transportation Accidents. Regarding non-radiological impacts of transportation accidents, in the most conservative case evaluated in the transportation analysis, there would be about 2.6 accidents per year involving trucks carrying spent IERs or empty casks, which is 0.0007 percent of the 2009 U.S. annual tractor-trailer truck accident rate. From these accidents, there would be about 0.02 traffic fatality per year, which is equivalent to 1 fatal accident every 50 years and represents 0.004 percent of 2009 U.S. tractor-trailer truck accident fatalities. There is little variation between these results for the various alternatives and transportation routes evaluated.

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[6] The maximally exposed individual (MEI) is the individual receiving the maximum exposure to a moving truck carrying a radioactive cargo. RADTRAN 6 models the MEI as a person standing as close as possible (30 meters from the center of the highway) to the moving truck, when the truck is moving slowly (about 24 kilometers per hour (15 miles per hour)) past the MEI.

Potential radiological impacts as a result of transportation accidents could occur under scenarios in which radioactive materials are and are not released from the casks. Regarding radiological impacts of transportation accidents in which no radioactive materials are released, in the most conservative case evaluated in the analysis, the collective population dose as a percentage of U.S. average annual background dose would be 0.01 percent, and the corresponding collective LCF as a percentage of estimated annual traffic fatalities involving spent IER shipments and of 2010 estimated U.S. cancer fatalities would be 0.136 percent and 7.7 x 10^{-9} percent, respectively. Again, there is little variation between these results for the various alternatives and representative transportation routes.

Regarding radiological impacts of transportation accidents in which radioactive materials are released from their shipping casks, the analysis separately examined the consequences of accidents involving Type A and Type B casks in which radioactive material is released. Due to design differences between these two types of shipping casks and the different classes of waste they would carry, the consequences of accidents involving these two cask types would be different. For the Type A cask accident scenario, the MEI dose and LCF as percentages of U.S. average annual background and 2010 U.S. total estimated cancer fatalities would be 31 percent and 1 x 10^{-8} percent, respectively. For the Type B cask accident scenario, at most, the MEI dose and LCF as percentages of background and 2010 estimated cancer fatalities would be 17 percent and 6 x 10^{-9} percent, respectively; and the corresponding collective dose and LCF percentages would be 0.22 percent and 2 x 10^{-7} percent, respectively.

Waste Management

Spent IER handling, transport, processing, and disposal, and construction of relatively small long-term spent IER storage facilities, would not result in substantial generation of radioactive, hazardous, mixed, or non-hazardous solid waste that would adversely affect safety, waste disposal capacity, or other resources. Liquid effluents (including stormwater) from facility operations and construction activities would be managed in accordance with applicable Federal and State regulations, including discharging within permitted limits (e.g., NPDES requirements).

Water Resources

With regard to water quality, only permitted liquid effluent discharges, within regulatory limits, would be allowed at all facilities, as applicable. Sediment discharges during construction of the relatively small long-term spent IER storage facilities in Alternatives 3 and 4A would be controlled through implementation of BMPs (e.g., earth berms, dikes, sediment fences). Accidental spills would be immediately addressed in accordance with SPCC plans. With regard to potential impacts on water supply, the small quantities of water that would be used at the spent IER processing facilities, and for dust suppression and other activities (e.g., equipment washing) at the waste disposal facilities and during construction of the relatively small long-term spent IER storage facilities in Alternatives 3 and 4A, would be expected to result in SMALL impacts to water supply.

ACRONYMS AND ABBREVIATIONS

AEA	Atomic Energy Act of 1954, as amended
ALARA	as low as reasonably achievable
BMPs	best management practices
BWR	boiling water reactor
CFR	Code of Federal Regulations
Ci	curie
CNS	Chem-Nuclear Systems
CO	carbon monoxide
CO_2	carbon dioxide
DOE	U.S. Department of Energy
EIS	environmental impact statement
EPRI	Electric Power Research Institute
FHWA	Federal Highway Administration
HAP	hazardous air pollutant
HDPE	high density polyethylene
HEPA	High Efficiency Particulate Air
HIC	High Integrity Container
IAEA	International Atomic Energy Agency
IER	ion exchange resin
ISCORS	Interagency Steering Committee on Radiation Standards
LCF	latent cancer fatality
LLRW	low-level radioactive waste
LSA	low specific activity
MEI	maximally exposed individual

NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act of 1969
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NO_2	nitrogen dioxide
NPDES	National Pollutant Discharge Elimination System
NPP	nuclear power plant
NRC	U.S. Nuclear Regulatory Commission
NRHP	National Register of Historic Places
OSHA	Occupational Health and Safety Administration
PL	Public Law
PM_{10}	particulate matter less than 10 microns in diameter
PWR	pressurized water reactor
Q	quantity, as in Q system
ROI	region of influence
SC DHEC	South Carolina Department of Health and Environmental Control
SCO	surface contaminated object
SHPO	State Historic Preservation Officer
SNF	spent nuclear fuel
SNL	Sandia National Laboratories
SO_2	sulfur dioxide
SOP	standard operating procedure
SPCC	spill prevention, control, and countermeasures
SRM	Staff Requirements Memorandum

T&E	threatened and endangered
THPO	Tribal Historic Preservation Officer
TI	transport index
TRAGIS	TRAnsportation Geographic Information System
USDOT	U.S. Department of Transportation
USFWS	U.S. Fish and Wildlife Service

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1 INTRODUCTION AND PURPOSE

This report presents a comparative environmental evaluation of six alternatives for handling low-level radioactive waste (LLRW) spent ion exchange resins (IERs) from commercial nuclear power plants (NPPs). It was prepared with assistance from the Environmental Safety and Testing Department and the Risk and Reliability Analysis Department of Sandia National Laboratories, Albuquerque, New Mexico. The evaluation has been conducted consistent with Option 2 in the U.S. Nuclear Regulatory Commission (NRC) staff's paper for the Commission, SECY-10-0043, "Blending of Low-Level Radioactive Waste," April 7, 2010 (NRC, 2010a). An NPP is defined as a thermal electric power generating station in which the heat source is one or more nuclear power reactors. Currently, there are 104 operating nuclear power reactors located at 65 commercial NPPs in the United States.

SECY-10-0043 identified policy, safety, and regulatory issues associated with LLRW blending, provided options for an NRC blending position, and made a recommendation for a future blending policy. Option 2 proposed that the staff revise the Commission position on blending to be risk-informed and performance based, the principal consideration being whether a final blended waste form could be safely disposed of. Proposed changes and clarifications to the existing blending positions included: (a) clarification that a site-specific intruder analysis must be performed to determine whether an intruder could be protected, or the conditions necessary for protection; (b) development of criteria defining acceptable homogeneity and sampling considerations; and (c) elimination of the "factor of 10 rule" for mixing of wastes that can be blended into a homogeneous mixture because the concentration of the final mixture will be relatively uniform in the context of a site-specific intruder scenario. The staff further proposed that this option would be implemented through a combination of rulemaking and issuance of guidance. Option 2 was approved by the Commission on October 13, 2010, in Staff Requirements Memorandum, SRM-SECY-10-0043, "Staff Requirements - SECY-10-0043 - Blending of Low-Level Radioactive Waste" (NRC, 2010b).

Additionally, in consideration of stakeholder concerns expressed regarding potential environmental impacts associated with the blending of certain LLRW, as documented in the NRC's Official Transcript of its January 14, 2010 "Public Meeting on Blending of Low-Level Radioactive Waste," (NRC, 2010c), the staff also proposed that "…disposal of blended ion exchange resins from a central processing facility would be compared to direct disposal of the resins, onsite storage of certain wastes when disposal is not possible and further volume reduction of the Class B and C concentration resins" (NRC, 2010a). The purpose of this report is to address this comparison of alternatives in the form of a comparative environmental evaluation of these IER waste-handling options. The six alternatives evaluated in this report include the four identified by the NRC staff in SECY-10-0043, Option 2, plus two additional alternatives that represent variations on the disposal of blended IERs from a central processing facility and volume reduction of the Class B and C concentration resins alternatives.

In the comparative environmental evaluation, the six alternatives are described and potential environmental impacts of the alternatives are: (1) identified for a range of resource or impact areas (e.g., air quality, ecological resources, public and occupational health, transportation, waste management, water resources) typically addressed in environmental assessment documents such as those prepared by the NRC staff under the National Environmental Policy Act of 1969 (NEPA), and the NRC's NEPA-implementing regulations in Title 10 (Energy) of the *Code of Federal Regulations* (10 CFR) Part 51; and (2) compared in terms of their relative potential effects on human health and the environment. To the extent practicable, the evaluation of potential environmental impacts identifies and accounts for generally accepted impact mitigation measures in each resource and impact area. As discussed in Section 3 of this report (Scope of the Evaluation), the six alternatives are generic and not location-specific—they generally are not intended to represent any actual actions or facilities. In addition, the comparative environmental evaluation of these alternatives is largely qualitative, with measures of potential environmental impacts expressed as characteristics as opposed to specific quantities or numerical magnitudes. An exception is that potential transportation impacts are assessed both quantitatively (based on numerically calculated or modeled consequences) and qualitatively. Note, however, that this report is not a NEPA environmental document because its purpose is not to assess the potential environmental effects of a proposed Federal (i.e., NRC) action and alternatives to a proposed action—it includes no staff finding or recommendation regarding a preferred alternative.

Furthermore, as discussed in Section 3, the evaluation is based on a number of conservative, often bounding assumptions regarding the alternatives and various aspects of the analysis. This approach is consistent with the assessment of generic, non-location-specific alternatives, for which exact data and information would not be available for use. Consequently, the staff used its professional knowledge, experience, and judgment to establish reasonable technical considerations, estimations, and approximations with regard to how the alternatives were described, would be implemented, and would potentially affect human health and the environment. The staff also took care not to underestimate the potential environmental effects and instead worked to bound the possible range of outcomes in most cases. Thus, the potential impacts of the six alternatives, if implemented in actual practice, would be expected to be of somewhat lesser magnitude than described in this report.

At commercial NPPs, IERs are used for water purification. These resins are small, bead-like materials that continuously remove dissolved radionuclides and other dissolved contaminants from the water. After some period of use, the IERs lose their ability to remove the contaminants from the water and must be replaced with fresh resins. In the industry, these used IERs are called *"spent"* IERs. Spent IERs contain radionuclides and are managed as LLRW.

The NRC divides LLRW into three classes—Class A, Class B, and Class C—depending on the concentrations of the different radionuclides in the waste and the long-term hazard those radionuclides present.[1] These LLRW classes were established by the NRC in 10 CFR 61.55. Class A LLRW is the lowest activity and least hazardous and Class C LLRW the highest activity

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[1] The LLRW classifications are related to the hazard that the wastes present after closure of the disposal facility and not the hazard at intermediate points in waste handling.

and most hazardous of the three classes.[2] Waste that exceeds the Class C limits is generally not acceptable for near-surface disposal. Licensees do not allow IERs to exceed the Class C limits, and waste at greater-than-Class C limits is not considered in this report. According to the NRC regulations in 10 CFR 20 Appendix G, LLRW is not required to be classified until being shipped for disposal. Thus, in this report, spent IERs that are not at the point of being shipped for disposal are referred to as "Class A, B, or C concentration spent IERs" and spent IERs being shipped for disposal are referred to as "Class A, B, or C LLRW."

Disposal facilities for LLRW in the U.S. are licensed by Agreement States[3] or the NRC to dispose of one or more classes of LLRW (Low Level Radioactive Waste Policy Amendments Act of 1985, Public Law (PL) 99-240),[4] and may also be subject to Low Level Radioactive Waste Compacts[5] that may restrict a facility's ability to accept waste from outside of a LLRW Compact. Currently, there are four Agreement State licensed LLRW disposal facilities, all of which are subject to LLRW Compacts. Of these facilities, one can accept and dispose of Class A LLRW from all 50 states.[6] The other three facilities can accept and dispose of Class A, B, and C LLRW, but only from a limited number of states; however, one of these three facilities recently received compact approval to accept LLRW from individual generators in additional states, but only on a case-by-case basis and subject to annual activity and volume limits (see Section 2.2 for details). (Tran and James, 2008; Waste Control Specialists, 2009; Waste Control Specialists, 2012; Herness, 2012a; Herness, 2012b) Thus, although all 65 operating commercial NPPs can currently dispose of their Class A LLRW spent IERs, more than 40 of the 65 NPPs have no access, or only limited access, to a disposal facility for their Class B and C LLRW spent IERs at this time.

Given the limited number of disposal facilities that can currently accept Class B and C LLRW, NPPs and LLRW processing and disposal companies are exploring alternatives for managing the Class B and C concentration spent IERs. One of these alternatives is to blend Class B and C concentration spent IERs to Class A concentrations. For this alternative, LLRW processing companies have proposed to use centralized processing facilities to blend, or mix, small

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[2] Activity is the level of radioactive emissions of a radionuclide, measured in becquerels (internationally) or in curies (in the U.S.).

[3] Agreement States are states that have been granted certain NRC regulatory authority under the Atomic Energy Act of 1954 (AEA), as amended. Section 274 of the AEA provides a statutory basis under which the NRC relinquishes to the Agreement States portions of its regulatory authority to license and regulate byproduct materials (radioisotopes), source materials (uranium and thorium), and certain quantities of special nuclear materials.

[4] The U.S. Department of Energy (DOE) also operates LLRW disposal facilities for wastes from DOE facilities and operations. DOE LLRW disposal facilities are not licensed by Agreement States or the NRC. Only Agreement State or NRC licensed LLRW disposal facilities are discussed in this evaluation because the commercial nuclear power reactor sites (NPPs) do not have access to DOE LLRW disposal facilities.

[5] The LLRW Compacts are congressionally approved entities that have been granted the authority to limit out-of-compact import and export of LLRW (Low Level Radioactive Waste Policy Amendments Act of 1985, Pub. L. No. 99-240, 99 Stat. 1842).

[6] An exception to this generalization is that the Columbia Generating Station, a commercial NPP in Washington State, is required to dispose of all of its Class A, B, and C LLRW at a facility located near Richland, Washington.

volumes of higher-activity Class B and C concentration spent IERs with larger volumes of low-activity Class A concentration spent IERs to produce Class A waste (Anderson, 2009; 2011).

The remainder of this report is organized as follows:

- Section 2 discusses the current status of the generation and disposal of spent IERs from commercial NPPs.
- Section 3 outlines the scope of the comparative environmental evaluation.
- Section 4 presents detailed descriptions of the six alternatives evaluated in this report for the handling of LLRW spent IERs.
- Section 5 presents the comparative environmental evaluation of the six alternatives.
- Section 6 is the list of references cited in this report.
- Appendix A provides the analysis of potential transportation impacts.

2 CURRENT STATUS OF THE GENERATION AND DISPOSAL OF SPENT ION EXCHANGE RESINS FROM COMMERCIAL NUCLEAR POWER PLANTS

This section provides background information on the nature and use of IERs at existing commercial NPPs, the generation of spent IERs and management and disposal of these as LLRW, and alternatives being considered by industry for managing Class B and C concentration spent IERs that currently have no direct disposal pathway.

2.1 Generation of Spent Ion Exchange Resins at NPPs

2.1.1 Ion Exchange Resin Composition and Use

Ion exchange resins used by commercial NPPs typically are small, bead-like materials composed of polystyrene and divinyl benzene. They are manufactured by several companies based on customer specification and application (Purolite®, 2011). Figure 1 is a photograph of IER beads.

Ion exchange resins remove impurities and improve the chemistry of water that is used in NPPs. In typical applications, IERs may be used for reactor water cleanup, pH adjustment, boric acid recovery, condensate polishing, spent fuel pool water cleanup, and removing contaminants from makeup water. Specific water chemistry is essential for keeping radiological exposure rates low, and for optimum heat transfer and equipment performance (DOE, 1993).

Figure 1 Photograph of Ion Exchange Resin Beads

Source: Wikipedia, 2012

At NPPs, the IERs are contained in tall cylindrical tanks known as resin beds. These beds vary in size depending on the system in which they are used, expected flow rate, and desired decontamination or demineralization factor. Resin beds are typically 0.85 m^3 (30 ft^3) each in volume and used in series (a combination of anion, cation, and mixed bed). Resin beds used for primary reactor coolant water cleanup are normally good for a fuel cycle (18 to 24 months). Some resin exchange systems are designed for reuse, employing a process called regeneration. This process involves reconditioning the resins for reuse similar to the backwash of a swimming pool filter. Resin beds are changed when they decrease in efficiency or can no longer be regenerated. (IAEA, 2002a)

2.1.2 Spent IER Generation and Management

The IERs are considered “spent” when they lose their ability to remove contaminants from the water and must be replaced with fresh resins. At this point, the spent IERs are sluiced from the resin beds into special containers, typically High Integrity Containers (HICs) or other appropriate liners. Construction materials for spent IER containers are selected to be appropriate for storage, shipment, and disposal, and these materials may consist of stainless steel, polyethylene impregnated concrete, high density polyethylene (HDPE), fiberglass–polyethylene, or coated carbon steel (NRC, 1989a).

The spent IERs may contain significant quantities of radionuclides, including fission, activation, and corrosion products. Radionuclides that may be present include barium-133, cesium-137, cobalt-58, cobalt-60, iron-55, manganese-54, nickel-63, technicium-99, and zinc-65 (NRC, 2007). The concentrations of radionuclides in the spent IERs are such that these IERs are managed as LLRW. For characterization purposes (in accordance with 10 CFR 61.55), spent IERs are sampled during the sluicing operations and analyzed to determine their isotopic identification, radionuclide-specific activities, and other waste characteristics.

There are many sizes (volumes) of the HICs or liners used for spent IER containerization. As discussed in Section 4.1.2, these HICs or liners are typically placed inside special casks for offsite shipment, designated as Type A and Type B shipping casks. These two types of shipping casks differ in size; and, typically, the larger Type A casks are used for transporting lower activity spent IERs whereas Type B casks are used for higher-activity spent IERS. For this evaluation, it is assumed that the liners shipped in Type A and Type B casks have volumes of 5.29 m^3 (187 ft^3) and 3.17 m^3 (112 ft^3), respectively (see Table A-1 in Section A.2.2, Appendix A). After being sluiced to HICs or liners, the resins are bulk dewatered to remove free-standing liquid. Additional information on spent IER dewatering is presented in Section 4.1.1.

Following the dewatering process, spent IER containers are normally placed inside shielded concrete containers and staged in shielded areas at the NPPs, where they are prepared for onsite storage or offsite shipment. Spent IERs from systems with low radiological constituent concentrations, such as make-up water, condensate polishing, and raw water purification, may not require shielded storage or special shipping considerations (NRC, 1985). When spent IERs are stored at NPPs for short periods of time, certain storage requirements must be met, such as the posting of warning signs, access control, inventory control, freeze prevention, radiological monitoring, and spill control measures. In addition, spent IER containers in storage must be inspected periodically to verify integrity. Long-term storage of spent IERs at NPPs is discussed in Section 4.2.4.

2.1.3 Estimated Annual Spent IER Volumes

Annual volumes of spent IERs generated by NPPs vary by plant design, with boiling water reactor (BWR) plants typically generating more spent IERs than pressurized water reactor (PWR) facilities (EPRI, 2007).[7] Table 1 presents the average spent IER volumes generated annually, as estimated by EPRI, by reactor type and waste class (EPRI, 2007). The volumes shown in Table 1 are for a single nuclear reactor of each type, based on the average for all reactors of each type.

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[7] This is because BWRs generally circulate more primary water through the reactor core than the PWRs. With more water moving through the core, there are more metals and fission products that must be removed from the water and, therefore, more spent IERs are generated.

Table 1 Average Annual Volume of Spent IERs Generated by Reactor Type
(m^3/year (ft^3/year))

REACTOR TYPE	AVERAGE ANNUAL VOLUME BY LLRW CLASSIFICATION[a,b]			TOTAL VOLUMES
	Class A	Class B	Class C	
Pressurized Water Reactors	12.2 (431)	3.1 (108)	0.4 (14)	15.7 (553)
Boiling Water Reactors	42.3 (1494)	3.5 (123)	0.2 (7)	46 (1624)

[a] For a single reactor of each type, based on the average for all reactors of each type.

[b] Based on four years of waste shipping records collected from 2003 through 2006 (EPRI, 2007).

Table 2 presents the average spent IER volumes, by reactor type and waste class, generated annually by all operating commercial NPPs, as estimated by EPRI using four years of waste shipping records from 2003 through 2006 (EPRI, 2007). For this comparative environmental evaluation, the volume estimates in Table 2 are assumed to be representative of current and future volumes, by waste class, of spent IERS from the fleet of 65 operating NPPs. These volumes were selected as being representative because the 2007 EPRI study is the most recent and comprehensive report available containing data on LLRW generation in the nuclear power industry. Thus, from Table 2, the average total volume of spent IERs generated annually is estimated to be 2568 m^3 (90,620 ft^3); and of that volume approximately 86 percent of the spent IERs contain Class A concentrations of radionuclides, 12 percent contain Class B concentrations, and 2 percent contain Class C concentrations.

Table 2 Estimated Average Annual Volumes of Spent IERs from All U.S. Operating Commercial NPPs
(m^3/year (ft^3/year))

REACTOR TYPE	AVERAGE ANNUAL VOLUMES BY LLRW CLASSIFICATION[a]			TOTAL VOLUMES[a]
	Class A	Class B	Class C	
Pressurized Water Reactors	818 (28,866)	204 (7210)	27 (944)	1049 (37,020)
Boiling Water Reactors	1397 (49,316)	115 (4048)	7 (236)	1519 (53,600)
Total Volumes by LLRW Classification	2215 (78,182)	319 (11,258)	34 (1180)	2568 (90,620)

[a] Based on four years of waste shipping records (2003 through 2006) collected by EPRI from 65 operating nuclear reactors (41 PWRs and 24 BWRs s) at 41 NPPs, and extrapolated by EPRI to all 65 operating commercial NPPs. EPRI rounded to 100 reactors rather than the actual 104 reactors (EPRI, 2007).

It is estimated that approximately 4 percent of the total volume of commercial LLRW generated in the U.S. annually is from NPP spent IERs. This is based on the estimated total average annual volume of spent IERs from all commercial NPPs from Table 2 (2568 m^3 (90,620 ft^3))

divided by the total volume of commercial LLRW disposed of in the U.S. in 2010 (approximately 60,770 m^3 (2,146,000 ft^3) from the U.S. Department of Energy's (DOE's) Manifest Information Management System database (DOE, 2011).

2.2 Disposal Options for the Spent Ion Exchange Resins

As discussed in Section 1, the spent IERs are classified as Class A, B, or C LLRW when shipped for disposal. Tables 1 and 2 in the NRC's regulation in 10 CFR 61.55 are used to determine if a container of spent IERs is classified as Class A, B, or C.[8] The distinction between Classes A, B, and C LLRW in 10 CFR 61.55 Tables 1 and 2 is based on the presence and specific activity of certain long- and short-lived radionuclides, and the threat those radionuclides pose to an inadvertent human intruder after closure of the LLRW disposal facility. Class A LLRW is the least hazardous of the three classes, posing a potential hazard to an inadvertent intruder for up to 100 years after closure of a disposal facility. Class B LLRW is more hazardous than Class A, and poses a potential hazard to an intruder for up to 300 years. Class C LLRW is the most hazardous of the three classes, and poses a potential hazard to an intruder for up to 500 years. (10 CFR 61.7(b) and 10 CFR 61.55(a)(2))

Currently, there are four licensed, operating LLRW disposal facilities in the United States—located near Richland, Washington; near Barnwell, South Carolina; in Clive, Utah; and near Andrews, Texas (Tran and James, 2008; Waste Control Specialists, 2009; Waste Control Specialists, 2012; Herness, 2012a). All four of these facilities were licensed and are regulated by Agreement States and are subject to Compacts that restrict LLRW generators' access to certain disposal facilities for certain classes of LLRW (Tran and James, 2008; Nuclear Power Daily, 2010).

The Richland facility currently provides disposal services for Class A, B, and C LLRW generated in the eight member states of the Northwest Compact (Alaska, Hawaii, Idaho, Montana, Oregon, Utah, Washington, and Wyoming) and the three member states of the Rocky Mountain Compact (Colorado, New Mexico, and Nevada). The Barnwell facility accepted Class A, B, and C LLRW from all 50 states until June 30, 2008, when access to this facility was restricted to LLRW generators in the three states in the Atlantic Compact (Connecticut, New Jersey, and South Carolina). The Clive facility accepts Class A LLRW from all 50 states and is under the jurisdiction of the Northwest Compact. (Tran and James, 2008; Nuclear Power Daily, 2010) The newest facility, near Andrews, Texas, accepts LLRW from the two states in the Texas Compact (Texas and Vermont). In addition, the Texas Compact recently approved individual applications from LLRW generators in states outside of the Texas Compact to dispose of Class A, B, and C LLRW at the Andrews, Texas, facility (Herness, 2012b). However, the Texas Compact has set an annual limit of 120,000 curies and 50,000 ft^3 for LLRWs imported from out-of-compact states (Herness, 2012b), thus limiting disposal of Class B and C LLRW at the Andrews facility from states outside of the Texas Compact.

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[8] The NRC's 1995 Branch Technical Position on Concentration Averaging and Encapsulation (NRC, 1995) provides additional guidance for determining the classification of LLRW when being shipped for disposal.

Thus, all 65 operating commercial NPPs have access to a disposal facility for their Class A LLRW spent IERs, but more than 40 of the 65 NPPs have no access, or only limited access, to a disposal facility for their Class B and C LLRW spent IERs at this time. As a result, NPPs and LLRW processing and disposal companies are exploring alternatives for managing Class B and C concentration spent IERs from NPPs that currently have no disposal pathway. One alternative that is currently available to NPPs is to store their Class B and C concentration spent IERs onsite at their own facilities until a disposal facility becomes available. Another alternative is for a LLRW processing company to take title of the Class B and C concentration spent IERs, volume-reduce these wastes using a thermal process, and ship the processed wastes for long-term storage at a licensed storage site pending the availability of a Class B and C LLRW disposal facility (Anderson, 2009). A third alternative is disposal of the Class B and C LLRW spent IERs at an appropriately licensed facility with compact approval to accept these wastes, if such a facility becomes available.

A fourth alternative is to blend the Class B and C concentration spent IERs to Class A concentrations. For this option, LLRW processing companies have proposed to use centralized processing facilities to blend, or mix, small volumes of higher-activity Class B and C concentration spent IERs with larger volumes of low-activity Class A concentration spent IERs to produce a homogeneous Class A waste that would be suitable for disposal as a Class A LLRW. LLRW processing companies have proposed that waste blending could be accomplished by mechanical mixing or thermal treatment processes (Anderson, 2009; 2011).

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3 SCOPE OF THE EVALUATION

This section describes the scope of the comparative environmental evaluation presented in this report. It introduces the six alternatives for handling LLRW spent IERs (Section 3.1) and discusses the general assumptions and approach used for the evaluation (Section 3.2). In addition, resource or impact areas eliminated from detailed consideration in this report are identified (Section 3.3).

3.1 Alternatives Evaluated

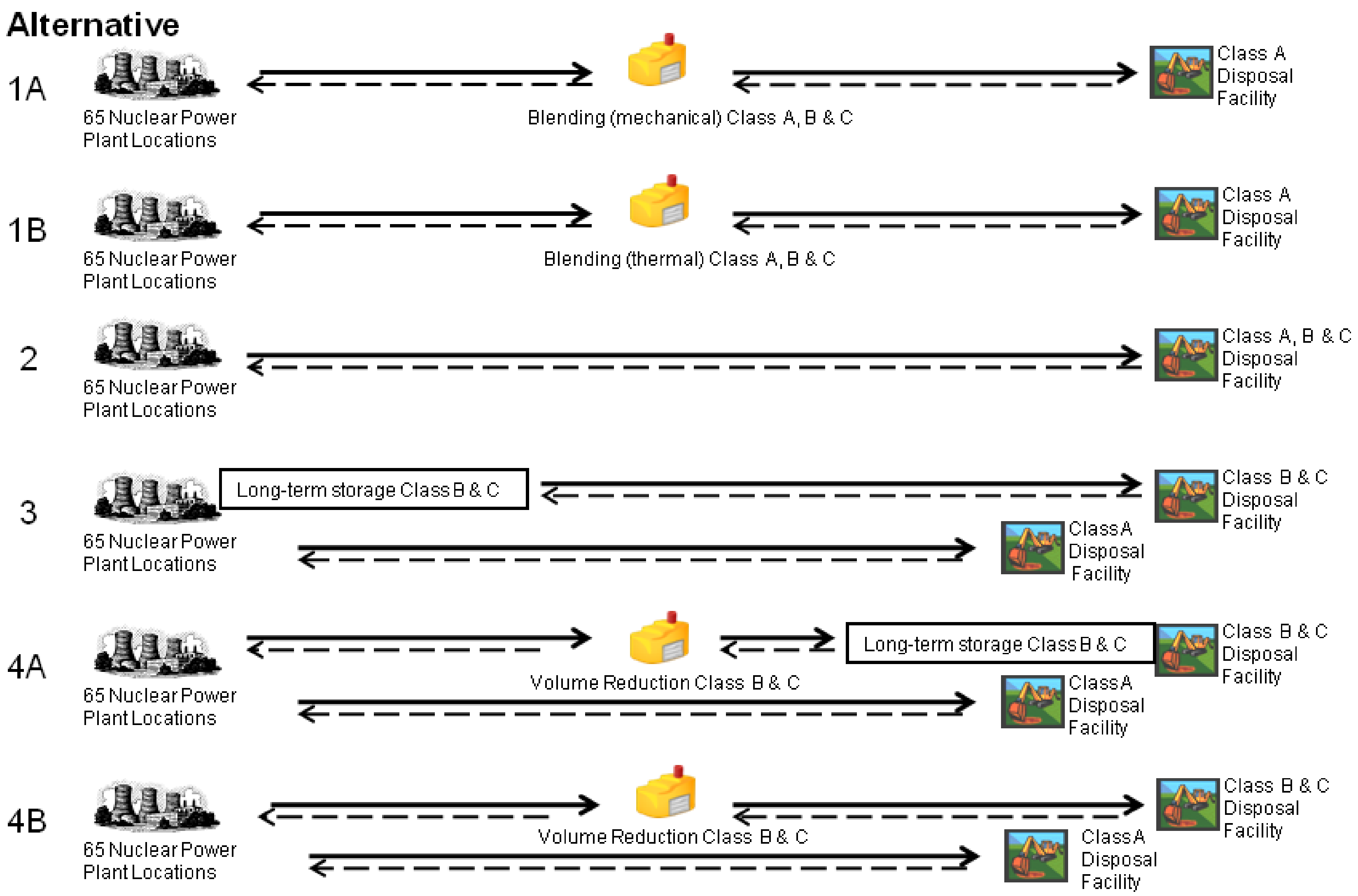
3.1.1 Brief Descriptions of the Alternatives

The six alternatives for handling LLRW spent IERs from commercial NPPs are listed and briefly described below. Figure 2 graphically presents these alternatives. As discussed in Section 1, these six alternatives are adapted from, and are consistent with, the four basic alternatives defined for evaluation by the NRC staff in Option 2 of SECY-10-0043 (NRC, 2010a) and approved by the Commission in SRM-SECY-10-0043 (NRC, 2010b). The alternatives are described in detail in Section 4.

The six alternatives evaluated are generic and not location-specific. A generic approach was taken since: (a) some of the alternatives (in particular Alternatives 1A and 1B, described below) are not currently in operation and may or may not be implemented; (b) actual implementation of alternatives could be at presently undetermined locations or employ somewhat different processes from what is currently proposed; and (c) some of the alternatives could be precluded by the implementation of others. However, for the purposes of this evaluation, it is assumed that any of the alternatives could be implemented. Additional assumptions regarding the six alternatives are included below and in the detailed descriptions in Section 4.

The six alternatives are:

- <u>Alternative 1A—Disposal of Blended Class A, B, and C Spent IER LLRW from a Central Processing Facility (using Mechanical Mixing)</u>. In Alternative 1A, the NPPs would package the Class A, B, and C concentration spent IERs in HICs or liners, which would be placed in shielded shipping casks (described in Section 4.1.2) and transported to a central processing facility for blending. At the central processing facility, the Class A and Class B and Class C concentration resins would be blended together in a mechanical mixing process and then dewatered in HICs or liners to create a final homogeneous mixture that meets Class A waste concentration requirements. The HICs or liners would then be placed in shielded shipping casks, as appropriate, and transported to a Class A LLRW disposal facility for disposal. Blending provides a disposal pathway for Class B and C concentration spent IERs in the absence of access to Class B and C disposal facilities.



NOTE: Solid lines represent trucks carrying spent ion exchange resins, and dashed lines represent trucks returning with empty shielded casks.

Figure 2 Graphical Presentation of the Six Alternatives Considered for Handling LLRW Spent Ion Exchange Resins

- Alternative 1B—Disposal of Blended Class A, B, and C Spent IER LLRW from a Central Processing Facility (using Thermal Processing). Alternative 1B is similar to Alternative 1A except that the central processing facility would use a thermal, superheated steam treatment process instead of mechanical mixing to blend Class A concentration spent IERs with Class B and Class C concentration spent IERs to create a waste form that meets Class A waste concentration requirements. The high temperature steam decomposes the organic resins and produces a more stable waste form (see Section 4.2.2).

Alternatives 1A and 1B represent variations on the "disposal of blended ion exchange resins from a central processing facility" alternative in SECY-10-0043, Option 2 (NRC, 2010a). These two alternatives are included in the comparative environmental evaluation because both mechanical mixing and thermal processing are assumed for this evaluation to be available technologies for the blending of Class A, B, and C concentration spent IERs.

- Alternative 2—Direct Disposal of Class A, B, and C Spent IER LLRW. For Alternative 2, it is assumed that a disposal facility would be immediately available to receive Class A, B, and C LLRW so that all spent IERs could be sent directly from the NPPs for disposal without long-term storage at the NPPs or intermediate, offsite processing. Handling and packaging of the spent IERs at the NPPs for offsite shipment would be conducted as in Alternative 1A. Alternative 2 represents the *"direct disposal of the resins"* alternative in SECY-10-0043, Option 2.

- Alternative 3—Long-term Onsite Storage of Class B and C Concentration Spent IERs, then Disposal. In Alternative 3, it is assumed that all Class A spent IERs could be directly disposed at existing Class A disposal facilities, but long-term storage of Class B and C concentration spent IERs at NPPs would be necessary after which disposal of these wastes could occur when a Class B and C disposal facility becomes available. It is further assumed that the long-term storage would require expansion of existing waste storage facilities and implementation of maintenance and monitoring programs for the stored wastes at NPPs. For this evaluation, long-term storage of the Class B and C concentration spent IERs is reasonably assumed to occur for a period of 20 years. At the end of the storage period, handling and packaging of the Class A, B, and C concentration spent IERs for offsite shipment would be conducted as in Alternative 1A. Disposal of Class B and C spent IERs is included in Alternative 3 to put it on an equal footing, from a comparative standpoint, with the other five alternatives, all of which include the ultimate disposal of all spent IERs. Because it is likely that a disposal facility licensed to accept Class B and C LLRW would become available in the future, all commercial NPPs could eventually have a disposal pathway for their Class B and C resins. Alternative 3 represents the *"onsite storage of certain wastes when disposal is not possible"* alternative in SECY-10-0043, Option 2.

- Alternative 4A—Volume Reduction of Class B and C Concentration Spent IERs at a Processing Facility, Long-term Storage, then Disposal. Alternative 4A would use a nearly identical thermal treatment process to that in Alternative 1B, with the exceptions that (a) only dewatered Class B and C concentration spent IERs would be processed in Alternative 4A to attain volume reduction of these wastes rather than blending these wastes with Class A concentration spent IERs to Class A concentrations; and (b) Alternative 1B includes no volume reduction. The final, volume-reduced waste form would be greatly improved and chemically stabilized as in Alternative 1B (see Section 4.2.2). As for the Class A spent IERs, it is assumed in this alternative that all of those wastes would be directly disposed at an existing Class A LLRW disposal facility. As discussed in Section 4.2.5, it is also assumed that the Alternative 4A thermal treatment process results in a volume reduction of 5 to 1 of the Class B and C concentration spent IERs (Lowman, 2011). However, a further premise of this alternative is that there is no immediate disposal option for the processed (volume-reduced) Class B and C concentration spent IERs, and that the processing facility would ship the treated wastes directly to a licensed LLRW storage facility, which is also a disposal facility seeking an Agreement State or NRC license or permission from the governing compact to dispose of Class B and C LLRW from all 50 states.[9] As in Alternative 3, it is assumed that 20 years of storage would take place prior to disposal; therefore, construction of a new waste storage facility or expansion of an existing storage facility at the waste disposal site would be necessary to accommodate long-term storage of the volume-reduced Class B and C concentration spent IERs. Handling and packaging of the spent IERs at the NPPs and the volume reduction facility for offsite shipment would be conducted as in Alternative 1A.

- Alternative 4B—Volume Reduction of Class B and C Concentration Spent IERs at a Processing Facility, then Disposal. Alternative 4B is similar to Alternative 4A except that it assumes that an LLRW disposal facility that can accept Class B and C wastes would be available for immediate transport and disposal of the processed (volume-reduced) spent IERs, and no long-term storage of the processed waste would be required.

Alternatives 4A and 4B represent variations on the *"further volume reduction of the Class B and C concentration resins"* alternative in SECY-10-0043, Option 2. Both of these alternatives are included in this evaluation because a disposal option for Class B and C wastes from all 50 states may not be available in the near-term, and long-term storage of these wastes would be necessary if a disposal facility is not immediately available (as in Alternative 4A).

3.1.2 Additional Assumptions Associated with the Alternatives

Additional key assumptions forming the basis of the descriptions of the alternatives and the evaluation of their potential environmental impacts in this report include:

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[9] Although the NRC staff believes that Alternative 4A represents a viable option for handling the Class B and C concentration spent IERs, the staff recognizes the possibility that some or all of the stored IERs might need to be shipped to an alternate disposal site at the end of the 20-year storage period if the disposal site with the long-term storage facility does not receive the necessary license or permission to accept the Class B and C spent IER LLRW for disposal.

- Each alternative is considered individually in the evaluation, i.e., each is assumed to be implemented at the exclusion of all the other alternatives; and all spent IERs generated at all 65 NPPs would be managed under each alternative.

- The current number of operating commercial nuclear reactors at the current number of NPP locations in the U.S. (104 operating reactors at 65 NPP locations), and the volumes and characteristics of the spent IERs generated at these NPPs, remain constant for the evaluation period.[10]

- All transportation of the untreated and treated (processed) spent IERs and returns of empty shipping casks would be by truck (because this is likely to be the most common mode of transport of spent IERs).

- All shipping casks are full when carrying spent IERs from an origin to a destination, and then always return empty to the origin; and separate shipping casks would be used to ship processed (blended or volume-reduced) spent IERs between the waste processing facilities and waste disposal sites (see Section A.1.2 of Appendix A for further explanation and additional consideration associated with this assumption).

- Only one centralized processing facility is considered to be in existence in Alternative 1A for blending by mechanical mixing, in Alternative 1B for blending by thermal processing, and in Alternatives 4A and 4B for volume reduction.[11]

- Ultimate disposition of all spent IERs in each alternative would be at a single Class A and a single Class B and C LLRW disposal facility.

The above six assumptions are necessary to establish a reasonable baseline for conducting the comparative environmental evaluation of the six generic, non-location specific alternatives. The use of these assumptions results in conservative estimates of potential impacts of each alternative in this evaluation because, if these alternatives were to be implemented in actual practice: (1) No single alternative would be selected by all 65 NPPs for managing all of their spent IERs; (2) Agreement State restrictions or other factors could prevent some NPPs from utilizing certain alternatives; (3) transport of some portion of the untreated and treated spent IERs and of returned empty casks could be by some mode other than by truck; and (4) there could be more than one waste processing (i.e., blending, volume reduction) facility (where applicable) and more than one Class A or Class B and C LLRW disposal facility accepting spent

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[10] This is a reasonable assumption because the timing of siting, financing, licensing, construction, and startup of operations of any new reactors cannot be predicted with certainty, some existing reactors may be shut down as new reactors come online (again uncertain), and any increase in the total number of operating reactors during the evaluation period is not expected to be large enough to significantly affect the environmental evaluation conclusions made in this report.

[11] This assumption is based on the consideration that the total volume of spent IERs generated annually at the currently existing 65 NPPs is relatively small (i.e., only approximately 4 percent of the total volume of commercial LLRW generated annually in the U.S. (see Section 2.1.3)), and the corresponding assumption that single central processing facilities would have sufficient capacity to handle all of the spent IERs.

IERs for processing and disposal, respectively, under any of the alternatives. Thus, the actual impacts of the alternatives, if implemented, would be of lesser magnitude because the environmental impacts would be divided among more than one alternative and among multiple locations for LLRW processing and disposal facilities.

3.2 General Evaluation Assumptions and Approach

As discussed earlier, the six alternatives evaluated in this report are generic and not location-specific. Also, the environmental analysis presented herein is largely qualitative, which is necessary and appropriate for a comparative environmental evaluation of generic, non-location-specific alternatives. An exception is that the assessment of potential transportation impacts is initially conducted quantitatively based on factors such as estimated numbers of shipments of full and empty shipping casks and representative transportation routes, as summarized in Section 5 and detailed in Appendix A (Transportation Analysis: Methodology, Assumptions, and Potential Impacts).

Furthermore, the baseline for this evaluation is current land use. This means that, with the exception of the long-term spent IER storage facilities considered in Alternatives 3 and 4A, this evaluation assumes that no new spent IER storage, handling, processing, and disposal facilities will be constructed and, therefore, does not revisit the impacts of construction of any of these facilities. This also means that all activities in the six alternatives would occur within existing facility footprints and boundaries. Where additional capacity would be needed for long-term storage of untreated or treated (processed) spent IERs in Alternatives 3 and 4A, it is assumed that this additional capacity could be created within the existing facility boundaries of the NPPs (Alternative 3) or the waste disposal site (Alternative 4) under existing operating licenses. In addition, it is assumed that all LLRW storage, processing, and disposal facilities considered in this evaluation operate under licenses from the NRC or an Agreement State, and that all activities conducted in the alternatives would be in compliance with all applicable Federal, State, and local legal and regulatory requirements.

Finally, the potential environmental impacts of closing and decommissioning any of the types of facilities considered in this report are not assessed. This is because those would be future impacts that are too uncertain to predict in a qualitative environmental evaluation of generic, non-location-specific alternatives.

The above assumptions and conditions are consistent with the statement in SECY-10-0043, Option 2 (see Section 1), which established the basis for this comparative environmental evaluation; and are necessary to place all six alternatives on a relatively equal footing so as to avoid any bias in the results of the comparative evaluation.

Potential environmental impacts of the six alternatives are identified and evaluated in Section 5 of this report for the following resource or impact areas: air quality, ecological resources, historic and cultural resources, noise, public and occupational health, soil, transportation, waste management, and water resources. Information on resource and impact area-specific methodologies and assumptions used in this evaluation are presented in Section 5.1. For reasons discussed in Section 3.3, the following resource or impact areas were eliminated from detailed consideration in this report: accidents and other off-normal conditions, environmental justice, geology and minerals, land use, socioeconomics, and visual and scenic resources.

A standard of significance has been established by the NRC for assessing environmental impacts, using the standards of the Council on Environmental Quality's regulations in 40 CFR 1508.27 as a basis (NRC, 2003). The NRC staff has implemented this standard for this comparative environmental evaluation and, as such, has assigned each potential impact one of the following three significance levels:

- SMALL. The environmental effects are not detectable or are so minor that they would neither destabilize nor noticeably alter any important attribute of the resource.

- MODERATE. The environmental effects are sufficient to noticeably alter, but not destabilize important attributes of the resource.

- LARGE. The environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

Note also that this generic, qualitative comparative environmental evaluation examines only the more important potential environmental impacts (i.e., it does not consider minor impacts that would have little effect on the natural or human environment, either individually or when combined with each other). In addition, to the extent practicable, the evaluation of potential environmental impacts identifies and accounts for generally accepted impact mitigation measures in each resource or impact area that would typically be employed in general industry practice. Cumulative impacts are not assessed because there is no basis for determining the past, present, and reasonably foreseeable future actions on which such an analysis could be based for generic, non-location specific alternatives.

3.3 Issues Eliminated from Detailed Consideration

Based on the assumptions discussed above, the NRC staff has determined that certain resource or impact areas would either not be affected or would sustain negligible impacts from implementation of the six alternatives, or that impacts could not be assessed. These resource or impact areas and the reasons for their elimination from further consideration in this report are as follows:

- <u>Accidents and Other Off-Normal Conditions</u>. Spent IER processing-, storage-, and disposal-related accident impacts and impacts due to other types of off-normal conditions (e.g., extreme weather events, earthquakes) were not evaluated because it is not feasible to develop accident or other off-normal event scenarios for generic, non-location-specific alternatives and for process options that may not exist in the future. Instead, it is assumed that analyses of credible accident scenarios and other off-normal credible events would have already been conducted and reviewed by Federal and State regulatory agencies for licensed and permitted LLRW processing, storage, and disposal facilities, and that appropriate controls and mitigation measures (e.g., fire and radiation protection systems) would have been considered when evaluating the consequences associated with these events.

Note, however, that the potential environmental impacts from radiological and non-radiological transportation accidents are addressed in this report, in Section 5.1 and Appendix A.

- Environmental Justice. This is not considered in the evaluation because the presence of minority and low-income populations cannot be established for non-location-specific alternatives.
- Geology and Minerals. As discussed earlier, the baseline for this evaluation is current land use and, as such, activities in the six alternatives would take place within the footprints and boundaries of existing facilities, established when these facilities were originally licensed and constructed. Also, it is anticipated that there would be minimal or no potential effects on geology and minerals due to the construction and operation of the relatively small long-term spent IER storage facilities considered in Alternatives 3 and 4A (see Sections 4.2.4 and 4.2.5). No additional activities would take place during facility operations in any of the alternatives that would affect regional or local geology or access to mineral resources.
- Land Use. Under the current land use assumption used in this evaluation, the primary land use impacts would have already occurred due to facility construction, and activities that would take place during facility operations would occur within existing facility footprints and boundaries. As a result, no activities during operations would further conflict with or otherwise affect onsite or nearby existing or proposed land uses.
- Socioeconomics. Only very small incremental increases in the numbers of employees at existing NPPs and LLRW processing and disposal facilities would be expected for the six alternatives, if any. Although construction of additional facilities for long-term spent IER storage in Alternatives 3 and 4A could result in somewhat larger numbers of workers, these increases would still be very small and would be temporary and of relatively short duration. Therefore, there would be little need for additional community services and negligible, if any, changes in regional and local economic conditions under these circumstances. Thus, socioeconomic impacts of the six alternatives would be extremely small.
- Visual and Scenic Resources. For the most part, the six alternatives would involve no new activities or land disturbances beyond existing facility footprints and boundaries. Construction of additional facilities for long-term waste storage in Alternatives 3 and 4A would occur within existing site boundaries with minimal visual impacts as compared to those of the existing NPP and waste disposal facilities at which they would be constructed. Therefore, minimal or no additional impacts to visual and scenic resources would be anticipated.

4 DETAILED DESCRIPTIONS OF ALTERNATIVES FOR HANDLING THE SPENT ION EXCHANGE RESINS

This section provides detailed descriptions of the six alternatives that are identified in Section 3.1 and evaluated in Section 5 of this report. The six alternatives share a number of common elements or steps, and Section 4.1 describes the elements that are common to some or all of the alternatives. Section 4.2 provides the detailed descriptions of the elements that are unique to each alternative.

4.1 Common Elements of the Alternatives

4.1.1 Dewatering of Spent IERs

Dewatering removes free-standing liquid from spent IERs, and would be conducted at both NPPs and waste processing facilities as necessary. It is an NRC regulatory requirement in 10 CFR 61.56(b)(2) that waste must be converted into a form that contains as little free standing and noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1 percent of the volume of the waste when the waste is in a disposal container designed to ensure stability, or 0.5 percent of the volume of the waste for waste processed to a stable form. For spent IERs not being shipped offsite for direct disposal, bulk dewatering would be employed. Bulk dewatering also removes free-standing liquid; however, there is no regulatory requirement to verify the final water content, and resins subjected to bulk dewatering could have water contents of >0.5 to 1 percent free-standing liquid.

In either case, dewatering is accomplished by a series of pumping and settling cycles. The HICs and liners used for spent IER containerization frequently have pre-installed dewatering equipment, commonly referred to as dewatering trees. A dewatering tree is connected to a dewatering skid containing hoses, pumps, valve actuators, instrumentation, and sample ports for monitoring (DTS, 2011). Even when dewatered to <0.5 to 1 percent free-standing liquid, the dewatered spent IERs may still have more than 50 percent of their initial water content because these resins absorb significant amounts of water.

4.1.2 Handling, Packaging, and Offsite Shipment of Spent IERs

The information in this section applies to both untreated and treated (processed) spent IERs from NPPs and waste processing facilities, respectively. Information on preparations for offsite transport and about offsite transport itself is included. Offsite transport from NPPs would be to a waste processing facility (Alternatives 1A, 1B, 4A, and 4B) or to an LLRW disposal facility (Alternatives 2 and 3). Offsite transport from a waste processing facility would be to an LLRW disposal facility (Alternatives 1A, 1B, and 4B) or to a facility for long-term storage of the processed waste located at a waste disposal facility site (Alternative 4A).

Offsite shipment of radioactive materials must meet the applicable regulatory standards. The NRC regulates packaging of radioactive materials for transportation under 10 CFR Part 71. The U.S. Department of Transportation (USDOT) regulates highway routing, placarding, occupational exposure and working conditions, and certain packaging requirements under 49 CFR Part 173 Subpart I.

4.1.2.1 Handling and Packaging

Figure 3 Type A Shipping Cask on Flatbed Trailer
Source: SC DHEC, 2007

Figure 4 Type B Shipping Cask on Flatbed Trailer
Source: DOE, 2012

Because of the radioactivity levels of the spent IERs, HICs or liners containing these materials are placed and transported in special shielded transportation containers. These shielded shipping containers are typically Type A or Type B certified shipping casks (see Figure 3 and Figure 4, respectively), depending on the A_2 value[12] of the spent IERs being shipped (10 CFR Part 71, Appendix A). Type B shipping casks are more robust than Type A casks and, therefore, would typically be used to ship spent IERs with higher radioactivity levels. Specifically, if the radioactivity of the spent IERs in the HIC or liner is less than or equal to the A_2 value, the spent IERs may be shipped in a Type A certified cask; and if the activity of the spent IERs exceeds the A_2 value, the spent IERs are usually shipped in a Type B certified cask. Additional information on Type A and B casks and their use for shipment of Class A, B, and C concentration and LLRW spent IERs is provided in Appendix A, Section A.2.2.

Prior to shipment from an NPP or a waste processing facility, the HICs or liners holding the spent IERS would be moved from their storage areas and placed in Type A or Type B shipping casks, as appropriate, which are mounted on appropriate trucks for offsite transport (see below). The HICs or liners would be handled using remote tools for lifting, but some worker contact would be necessary to verify proper rigging and placement.

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[12] The A_2 value is the maximum amount of radioactive material (measured in becquerels or curies), other than special form, Low Specific Activity (LSA), and Surface Contaminated Object (SCO) materials, permitted in a Type A package. This value is either listed in 10 CFR Part 71, Appendix A, Table A-1, or may be derived in accordance with the procedures prescribed in 10 CFR Part 71, Appendix A. (10 CFR 71.4) (See definitions of LSA and SCO materials in 10 CFR 71.4.)

4.1.2.2 Offsite Shipment

The loaded shipping casks would be transported on large, legal weight or overweight trucks (usually tractor-trailer trucks with semi-detached flatbed trailers). As discussed in Section A.2.2 of Appendix A, a truck can carry one Type A or one Type B shielded cask. Truck shipments of spent IERs in Type A and Type B casks are generally transported on interstate highways, and on limited-access or other primary highways where interstate highways are not available.

4.1.2.3 Estimated Annual Truck Shipments for the Six Alternatives

For the quantitative evaluation of potential transportation impacts in Appendix A, the NRC estimated the annual numbers of truck shipments for each of the six alternatives. For this evaluation, the NRC assumed that the shipping casks are full when carrying untreated or treated (processed) spent IERs and return empty to the shipment origin, and that there is one truck carrying a single Type A or Type B cask per shipment. The total number of annual shipments (or trips) per year for each alternative depends on factors such as the annual volume, the A_2 value of the spent IER shipments, and capacities of the shipping containers. The approximate numbers of these shipments for each alternative are estimated in Section A.2.3 of Appendix A.

4.1.3 Disposal of Untreated and Treated Spent IERs

The information in this section applies to all six alternatives, in which either untreated or treated (processed) spent IERs would ultimately be disposed of at appropriately licensed LLRW disposal facilities.

At disposal facilities licensed for disposal of Class A, B, and C LLRW, the HICs or liners would be removed from the shielded Type A or Type B shipping casks by crane and placed in the disposal system. Several types of disposal systems are used for LLRW spent IERs, depending on the waste classification and the nature of the disposal facility. To protect disposal site workers from radiation and to provide long-term waste stability, many LLRW disposal facilities place the HIC or liner inside a concrete container. Spent IERs that are managed in HICs may not have to be placed in concrete containers because the HICs provide the structural stability that is required by 10 CFR 61.56 for Class B and C LLRWs. Several concrete containers or HICs may be arranged in the disposal area or disposal trench. The concrete containers are sometimes referred to a silos or disposal vaults. Figure 5 is a photograph of a set of disposal vaults in a trench being used for disposal of Class B

Figure 5 Low-Level Radioactive Waste Disposal Vaults in a Disposal Trench
Source: SC DHEC, 2007

and C LLRW. Once a disposal area or trench is filled with concrete containers and HICs, the voids between the containers are backfilled with flowable sand or soil.

Sand, soil, stabilized Class A LLRW, or Class B LLRW may be placed on top of the concrete shells and HICs. After a trench or disposal cell is filled, a partial cover or cap is placed on the cell to prevent water infiltration. After a set of cells is filled, a final cover could be built over them, or the final cover could be built during closure of the entire disposal facility. The final cover would incorporate design elements protective of human health and the environment, including features to limit water infiltration and prevent bio-intrusion and inadvertent human intrusion (10 CFR 61.12(b)).

4.2 Specific Elements of the Alternatives

4.2.1 Alternative 1A—Disposal of Blended Class A, B, and C Spent IER LLRW from a Central Processing Facility (using Mechanical Mixing)

In Alternative 1A, the Class A, B, and C concentration spent IERs would first be dewatered in HICs or liners at the NPPs and then transported to the central processing (blending) facility as described in Sections 4.1.1 and 4.1.2, respectively. At the processing facility, the Class B and C concentration spent IERs would be mechanically mixed with Class A concentration resins in the proper proportions to create a homogeneous mixture that meets Class A requirements.

At the blending facility, the incoming HICs or liners containing the spent IERs would first be transferred into a shielded loading bay, and their contents would then be transferred into blending input holding tanks that are segregated by spent IER activity levels. If the spent IERs were left in HICs or liners for extended periods of time before arriving at the processing facility, the resins may have compacted in the bottoms of the containers. If compaction occurs, the spent IERs may require agitation, either hydraulically or mechanically, before they can be completely removed from the HICs or liners. (IAEA, 2002a)

Next, the Class A and Class B, and C concentration spent IERs would be pumped from the input holding tanks into the blending tank in the proper proportions such that the final blended mixture would meet Class A LLRW requirements. The IERs would be mechanically mixed in this tank to eliminate hot spots caused by the clumping of Class B and C concentration spent IERs. The chemical structure of the spent IERs does not change in the blended resin waste form because the mechanical mixing process is conducted at ambient temperature (i.e., without artificial heating or cooling), and this process does not change the volume of the spent IERs (EnergySolutions, 2009).

Mechanical blending has not been used on a commercial scale, but the NRC believes that mechanical blending would produce little ancillary waste because (1) the same input tanks and mixing tank could be used for each batch (thus little incidental waste would be produced between batches) and (2) mechanical mixing does not increase or decrease the volume of the spent IERs or transfer the radioactivity to other media. Additionally, a mechanical blending facility would use small quantities of water; and because of the high cost of managing radioactive water, a mechanical blending facility would minimize the use of water in the processing areas. Also, as with any small industrial facility, water may be needed for maintenance, domestic purposes and cooling, and it is anticipated that the amounts of water used for these purposes would not be significant.

When the final spent IER mixture is homogeneous, it would be transferred directly into HICs or liners for additional dewatering (see Section 4.1.1), or transferred into a tank for dewatering and then transferred to HICs or liners. Ion exchange resins readily absorb water, thus potentially requiring dewatering before leaving the mechanical mixing facility, even if they were dewatered at the NPPs (IAEA, 2002).

Handling and packaging of the blended waste for offsite transport from the central processing facility, transportation of the waste from the processing facility to the LLRW disposal facility, and disposal of the blended waste would be conducted as discussed in Sections 4.1.2 and 4.1.3 above.

4.2.2 Alternative 1B—Disposal of Blended Class A, B, and C Spent IER LLRW from a Central Processing Facility (using Thermal Processing)

Alternative 1B is essentially the same as Alternative 1A in the following areas: spent IER dewatering and packaging at the NPPs; offsite transport from the NPPs to the central processing (blending) facility; pre- and post-processing operations at the blending facility (excluding dewatering of the processed spent IERs); transport of processed spent IERs from the blending facility to the LLRW disposal facility; and subsequent waste disposal operations. Where the two alternatives differ, however, is in the blending process used, in that Alternative 1B involves the addition of mixing agents and thermal treatment of the resins with superheated steam rather than mechanical mixing as in Alternative 1A. In Alternative 1B, the Class A and Class B and C concentration spent IERs would be pumped from their segregated input holding tanks to a pyrolyzer (the primary thermal treatment tank used in the thermal processing), along with various mixing agents (such as oils, charcoal, graphite, sludges, nitrates, and phosphates) that are added to promote formation of a stable final waste form (Mason et al., 1999). Specifically, the mixing agents are added to supply the reactants required to chemically transform the spent IERs into a chemically stable waste form. In the process, the quantity of these agents would be closely monitored to ensure that the volumes of the final waste forms match the input volumes and that the final waste forms meet Class A requirements (Lowman, 2011). This mixture will henceforth be referred to in this section as “waste”.

High-temperature (800^{o}C (1,472^{o}F)) steam would be introduced into the bottom of the pyrolyzer and allowed to flow upward through the waste. The flow of steam through the waste transforms the waste from a slurry into a fluidized bed with almost no thermal gradient and extremely efficient mixing properties. The organic components of the waste, which include the resins, are chemically transformed through a process known as destructive distillation, which superheats and vaporizes all absorbed water and then decomposes the organic resins into a solid residue (weighing approximately one third of the original resin weight) and a combination of off-gases and vapors (IAEA, 2002a). The solid residue chemically reacts with the mixing agents described above to begin the formation of the chemically stable waste form. Gases released from this process, including carbon dioxide (CO_2), carbon monoxide (CO), hydrogen, steam, and acidic off-gasses (e.g., halogens and sulfur vapors), are separated from the solid waste by ceramic filters and then processed in an off-gas handling system.

Once the thermal processing in the pyrolyzer is complete, the mixture (consisting of 99.7 percent of the spent IERs' radionuclides, carbon, metals, and oxides) would be passed through an electrically heated reformer (a secondary pyrolyzer) where high-temperature steam is again introduced creating another fluidized bed (Mason et al., 1999). The reformer gasifies the remaining carbon into CO_2 and CO, which are separated from the solid waste by ceramic filters and processed through the off-gas system (IAEA, 2002a).

The off-gas system transfers the separated gases through a heater–evaporator, which would oxidize any organic synthesis gases into steam, CO_2 and CO, and vaporize excess scrubber water. The vaporization process is used to keep the scrubbing water solution at between 10 and 20 percent dissolved salts. The wet gases then pass through a rotary atomizer scrubber to convert halogens and sulfur from a vapor to a salt solution, which is then passed back through the scrubber water. The scrubbed gases then pass through a High-Efficiency Particulate Air (HEPA) filter before being released to the atmosphere. The salts from the evaporator and scrubber are then combined and dried for direct disposal as LLRW separate from the primary solid waste form (i.e., the Class A LLRW) (Mason et al., 1999). These incidental wastes are relatively small in volume and contain less than one-half of one percent of the incoming radioactivity. The thermal process produces no liquid releases and no secondary solid wastes, except the mercury adsorber media (THOR^{sm}, 2006), a hazardous waste stream that would be managed in accordance with Federal and State regulations. As with any small industrial facility, water may be needed for maintenance and domestic purposes. Steam requirements would require roughly 10 gallons per minute (THOR^{sm}, 2006) when operating, and this use would equate to slightly more than 1 million gallons per year, which would not be unusual for an industrial facility.

The thermal processing creates a greatly improved, more stable waste form over the original, unprocessed spent IER waste form. This final waste form appears to be granular to powdery (Studsvik, 2012). Gas production in the stabilized waste form would decrease by many orders of magnitude as compared to that in the unprocessed spent IERs or would potentially stop altogether. The metals and oxides in the new waste form would not absorb water; thus, the potential for swelling is removed and the lack of water in the solid final waste form improves chemical compatibility with the HICs or liners and considerably reduces the leachability of the radionuclides in a disposal system. (Mason et al., 1999)

4.2.3 Alternative 2—Direct Disposal of Class A, B, and C Spent IER LLRW

In Alternative 2, all Class A, B, and C concentration spent IERs would be dewatered and packaged at the NPPs and then transported to an LLRW disposal facility for direct disposal, as described in Sections 4.1.1, 4.1.2, and 4.1.3.

4.2.4 Alternative 3—Long-Term Onsite Storage of Class B and C Concentration Spent IERs, then Disposal

Alternative 3 comprises three separate time periods, or stages: (1) “Years 1–20”, during which all Class A LLRW spent IERs are shipped from the NPPs for direct disposal and all Class B and C concentration spent IERs are stored onsite at the NPPs; (2) “Year 21”, during which all Class A LLRW spent IERs continue to be shipped for direct disposal and all of the stored Class B and C concentration spent IERs are also shipped for disposal; and (3) the period “After Year 21”, during which all Class A, B, and C LLRW spent IERs are shipped for direct disposal. The basis for the 20-year long-term storage assumption is discussed in Section 3.1.

Long-term storage at the NPPs would be in on-site storage facilities. For long-term storage, it is assumed that the HICs or liners at each NPP would be placed in concrete shielding cells that are inside a heated building to prevent the spent IERs from freezing. Some expansion of existing LLRW storage facilities at each of the NPPs would likely be required to store 20 years’ accumulation of Class B and C concentration spent IERs. To provide a sense of the scale of these long-term storage facilities, the area (“footprint”) that a typical storage building would occupy at an NPP is estimated below.

As shown in Table 1 in Section 2.1.3, the average PWR and BWR units produce 3.5 m^3 and 3.7 m^3, respectively, of Class B and C concentration spent IERs per year. Thus, on average, BWRs produce more Class B and C concentration spent IERs per year than PWRs. To bound the results, the calculations that follow are conservatively based on the average annual volume of spent IERs generated by BWRs.

As discussed in Sections 2.1.2 and A.2.2, at the NPPs, the spent IERs are placed in special containers (HICs or liners) that differ in size. For this evaluation, it is assumed that the higher activity Class B and C concentration spent IERs would be placed, stored, shipped, and disposed in L8-120 liners with an internal volume of 3.17 m^3 (112 ft^3) and a diameter of 1.55 m (5.08 ft) (see Table A-1 in Appendix A).[13] Therefore, the average BWR unit would produce 24 liners of Class B and C concentration spent IERs over 20 years (3.7 m^3 of spent IERs per year ÷ 3.17 m^3 of spent IERs per liner x 20 years = 24 liners). Based on this average accumulation of 24 liners per year for an average BWR unit, conservatively, the average NPP would accumulate 39 liners of Class B and C concentration spent IERs over a 20-year period ((24 liners per reactor unit over 20 years x 104 reactor units) ÷ 65 NPP locations = 39 liners per NPP location). The results are rounded up to the next whole number.

For long-term storage, each liner would be placed in a cylindrical concrete cell to provide shielding. Based on the estimated activity of the Class B and C spent IERs and MicroShield calculations (Grove, 2005), it is conservatively estimated that the concrete cells would need to be about 0.61 m (2 ft) thick. With 0.61-m (2-ft) thick walls, the cells would have an outer diameter of 2.77 m (9 ft) (1.55 m liner diameter + (2 x 0.61 m) = 2.77 m). Assuming an aisle

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[13] The model L8-120 liner is used for illustrative purposes in the evaluation. Other liner types are available for use for containing spent IERs.

width of 3 m (10 ft) between the cells to allow for equipment movement and inspections, the “footprint” of storage space for each shielding cell would be about 5.8 m by 5.8 m (19 ft x 19 ft), or about 33.6 m^2 (360 ft^2). Thus, it is estimated that the 39 shielding cells, on average per NPP, could be stored in an expanded building space with a footprint of about 1440 m^2 (about 15,500 ft^2), allowing for the 39 cells plus 10 percent for the walls and ancillary parts of the storage structure. It is possible that such storage facilities at the NPPs could be constructed in stages over the 20-year period rather than all at once. Since NPPs occupy sites of about 200 to 400 hectares (500 to 1000 acres) (Gonveau, 2005), a 1440-m^2 (15,500-ft^2) building expansion would occupy a very small portion, about 0.04 to 0.07 percent, of the total NPP site area, on average.

Long-term storage of the Class B and C concentration spent IERs would also require an ongoing storage facility monitoring and maintenance program at each NPP. Several technical factors would need to be considered in the monitoring and maintenance program, such as gas generation in the storage containers, swelling of the IERs due to water absorption, IER compaction, and container integrity. Spent IER containers prepared for long-term storage require a venting system due to possible build-up of flammable gasses, including hydrogen gas (URS, 2009). Also, because the IERs absorb water from the atmosphere, they may have to be dewatered multiple times over their extended storage period. Enough empty space must be available in the HICs or liners to allow for swelling of the IERs due to absorption of water. Furthermore, if compaction occurs, the stored IERs must be mechanically or hydraulically agitated. The integrity of the containers would need to be examined periodically to ensure that no undesirable performance degradation occurs and that no water is leaking from the storage containers. (IAEA, 2002a) HDPE HICs and liners that are not reinforced are not approved for long-term storage due to chain scission and cross-linking in the polymer from the high radiation levels (NRC, 1989b).

After the 20 years of storage, the Class B and C concentration spent IERs would be prepared as necessary and transported from the NPPs to the Class B and C LLRW disposal facility as described in Section 4.1.2, and disposed as described in Section 4.1.3.

4.2.5 Alternative 4A—Volume Reduction of Class B and C Concentration Spent IERs at a Processing Facility, Long-Term Storage, then Disposal

In Alternative 4A, the Class A LLRW spent IERs would be sent from the NPPs for direct disposal, and the Class B and C concentration spent IERs would be transported from the NPPs to a central processing facility for volume reduction by thermal treatment, followed by transport of the processed Class B and C concentration spent IERs to a disposal site where they would be stored until disposal at that site is possible (assumed to be 20 years for this evaluation; see Section 3.1). The Class A, B, and C concentration spent IERs would first be dewatered and packaged at the NPPs, after which the Class A resins would be transported to the Class A LLRW disposal facility and the Class B and C concentration resins would be transported to the processing (volume reduction) facility, as described in Sections 4.1.1 and 4.1.2. Direct disposal of the Class A resins would be conducted as described in Section 4.1.3.

The thermal waste processing technology used in Alternative 4A is nearly identical to that in Alternative 1B, with the exceptions that (a) in Alternative 4A, the Class B and C concentration spent IERs are not mixed and blended with Class A concentration spent IERs, and the process is altered to result in a reduction in waste volume. A final volume reduction of five to one in the treatment process is assumed (Lowman, 2011). The resulting waste form would need to be disposed in a facility licensed to accept Class B and C LLRW. The final, volume-reduced waste form would be greatly improved and stabilized as in Alternative 1B (see Section 4.2.2).

Packaging and transportation of the Class B and C concentration processed waste forms from the volume reduction facility to the waste disposal site where the waste would be stored for 20 years would be conducted as discussed in Section 4.1.2.

Storing a 20-year accumulation of processed (volume-reduced) Class B and C concentration spent IERs from all 65 NPPs would require the construction of a waste storage facility or expansion of an existing storage facility at the disposal site awaiting a license or other permission to dispose of Class B and C LLRW. Containerization and shielding of these spent IERs would be as described in Section 4.2.4 for long-term storage of Class B and C concentration resins at the NPPs, except that storage of the processed Class B and C concentration resins at the waste disposal site could be on concrete pads without freeze protection (i.e., without needing to be in a building) since the thermally-treated spent IERs would neither contain nor absorb water (see Section 4.2.2).

It is estimated that about 2227 containers (liners) of Class B and C concentration spent IERs would be generated by the 65 NPPs over 20 years (353 m^3 of Class B and C concentration spent IERs per year (from Table 2) ÷ 3.17 m^3 of spent IERs per liner x 20 years = 2227 liners). With a volume reduction factor of five in processing, a total of about 446 containers of processed Class B and C concentration spent IERs would be produced over the 20-year period (2227 containers ÷ 5 ≈ 446 containers). Based on the estimated 33.6 m^2 (360 ft^2) of required storage space per shielded cell (see discussion in Section 4.2.4), it is estimated that the 446 shielding cells could be stored in an area with a footprint of about 16,500 m^2 (about 177,000 ft^2), allowing for the cells plus 10 percent for the edges and ancillary parts of the storage facility. It is likely that such a storage facility would be constructed in stages over the 20-year period rather than all at once. Assuming that the LLRW disposal site occupies a total area of about 500 hectares (1240 acres),[14] the storage facility would occupy less than 1 percent of the total site area.

As in Alternative 3, long-term storage of the wastes at the waste disposal site would require an ongoing monitoring and maintenance program. However, for Alternative 4A, the maintenance and monitoring requirements would be minimal as compared to those at the NPPs discussed in Section 4.2.4. This would be the case due to the improved, stabilized waste form produced in the thermal volume reduction process, which is not subject to conditions such as gas generation

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[14] For example, the recently licensed LLRW disposal facility near Andrews, Texas, occupies an area of about 542 hectares (1338 acres) (Waste Control Specialists, 2011).

and swelling due to water absorption. At the conclusion of the 20-year storage period, the processed Class B and C spent IERs would be disposed of as discussed in Section 4.1.3.

4.2.6 Alternative 4B—Volume Reduction of Class B and C Concentration Spent IERS at a Processing Facility, then Disposal

Alternative 4B is identical Alternative 4A with the exception that the thermally processed Class B and C spent IERs produced in the volume reduction process would be transported for immediate disposal at a licensed Class B and C LLRW disposal facility without any intermediate storage.

5 COMPARATIVE ENVIRONMENTAL EVALUATION

This section presents the comparative environmental evaluation of the six alternatives identified by the NRC staff for handling LLRW spent IERs. This evaluation was performed based on the assumptions and approach described in Section 3 and the detailed descriptions of the alternatives presented in Section 4. In the discussion that follows, Section 5.1 presents potential environmental impacts of the six alternatives, preceded by discussions of the resource and impact area-specific methodologies and assumptions used to assess the environmental effects and possible mitigation measures that could be employed to minimize or mitigate potential impacts. Section 5.2 summarizes the comparative environmental evaluation results.

5.1 Potential Environmental Impacts

5.1.1 Overview

The NRC staff's general analytical, stepwise approach to the assessment of potential environmental impacts in this evaluation was to: (1) identify the set of component activities that comprise the various alternatives; (2) identify and assess the nature of the potential environmental effects of each component activity on each resource or impact area; (3) consider generally accepted measures that could be employed where necessary to mitigate potential environmental impacts; and (4) evaluate the potential impacts of each of the six alternatives by considering the individual environmental effects of their activities and associated mitigation measures. For each alternative, for each resource or impact area, an impact significance level of SMALL, MODERATE, or LARGE is assigned as discussed in Section 3.2, and the rationale for each rating is discussed. This approach provides a consistent measure of potential environmental impacts across the alternatives.

As discussed above, the NRC staff initially identified a set of component activities that comprise each of the six alternatives. Some of these activities may be common to some or all of the six alternatives, while others may be unique to specific alternatives. Component activities include individual, specific actions (e.g., blending of spent IERs at a central processing facility) and combinations of several actions having similar types of environmental consequences (e.g., spent IER "handling", which includes packaging, staging, loading, or unloading of untreated or treated (processed) spent IERs). Seven component activities were identified and considered in this evaluation for identifying potential environmental impacts of the six alternatives. These activities and the alternatives in which they are included are shown in Table 3.

Resource or impact area-specific methodologies and assumptions used in this evaluation are described in Section 5.1.2, and possible mitigation measures that could be employed to minimize or prevent potential impacts are discussed in Section 5.1.3. This is followed by the evaluation of potential environmental impacts of the six alternatives in Section 5.1.4.

5.1.2 Resource and Impact Area-Specific Methodologies and Assumptions

The methodologies and assumptions used in the evaluation of potential impacts for each resource or impact area considered are described in this section.

Table 3 Component Activities of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins

COMPONENT ACTIVITIES	INCLUDED IN ALTERNATIVES:					
	1A	1B	2	3	4A	4B
1. Handling of untreated or treated (processed) spent IERs at NPPs, waste processing (blending or volume reduction) facilities, long-term storage facilities, or LLRW disposal facilities (includes activities related to packaging, staging, loading, and unloading of spent IERs). Also includes short-term storage that may occur at NPPs, waste processing facilities, and LLRW disposal facilities.	X	X	X	X	X	X
2. Blending of Class A, B, and C concentration spent IERs at a central processing facility using mechanical mixing.	X					
3. Thermal processing (blending or volume reduction) of spent IERs at a central processing facility (i.e., blending of Class A, B, and C concentration spent IERs and volume reduction of Class B and C concentration spent IERs).		X			X	X
4. Construction (expansion) of long-term spent IER storage facilities at existing NPPs or at a waste disposal site[a]				X	X	
5. Long-term storage of untreated or treated spent IERs and associated inspection and maintenance activities.				X	X	
6. Offsite transport of untreated or treated spent IERs from NPPs to waste processing facilities, NPPs to LLRW waste disposal facilities, or waste processing facilities to LLRW disposal facilities, and return shipping of empty casks from shipment destinations.	X	X	X	X	X	X
7. Disposal of untreated or treated LLRW spent IERs.	X	X	X	X	X	X

[a] At NPPs, existing LLRW storage facilities would be expanded for the storage of spent IERs rather than new storage facilities being constructed for this purpose.

5.1.2.1 Air Quality Impacts

Air quality impacts could consist of potential effects on ambient air quality from activities conducted in the alternatives. For this evaluation, radiological and non-radiological air quality impacts are discussed separately. Spent IER handling, processing, storage, and disposal facilities and trucks transporting spent IERs would be subject air quality regulations, as applicable.

5.1.2.1.1 Radiological Impacts

The radiological air quality impact evaluation examined potential releases of radionuclides due to air emission-producing activities in the alternatives. The degree of hazard to the public is directly related to the type and quantity of radioactive materials released, and the extent of exposure of individuals to the released materials. The evaluation reasonably assumes that applicable regulatory standards for air quality would not be exceeded because the facilities would be in compliance with all applicable regulatory requirements and would employ physical controls (e.g., air pollution control equipment) and other mitigation measures as necessary to meet air quality criteria. Atmospheric releases of radiological constituents must comply with the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR Part 61) or stricter state requirements. The radiological requirements in NESHAPs specify that the total radiological emissions from a facility cannot cause any member to the public to receive an annual dose of radiation in excess of 0.1 millisieverts/year (mSv/year) (10 millirem/year (mrem/year)).[15] Off-gas monitoring is required under NESHAPs if the predicted annual dose to a member of the public is more than 1 percent of the 0.1 mSv/year limit (40 CFR Part 61, Subpart H).

5.1.2.1.2 Non-radiological Impacts

The non-radiological air quality evaluation examined whether component activities comprising the alternatives could cause emissions of criteria air pollutants or hazardous air pollutants (HAPs). Criteria air pollutants under the National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50) consist of particulate matter less than 10 microns in diameter (PM_{10}), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), lead, and ozone. HAPs are NESHAPs-defined chemical emissions in 40 CFR Part 61. The evaluation examined the emissions that could occur as a direct result of activities at a facility. It was assumed that if criteria air pollutants or HAP emissions could exceed applicable regulatory standards, air pollution controls and mitigation measures would be employed as necessary to bring the emissions into compliance.

5.1.2.2 Ecological Resource Impacts

Impacts on ecological resources could include potential effects on plants and animals that live on, or otherwise rely on, lands at a facility and contiguous lands for their continued existence. Evaluation of potential ecological impacts generally addresses potential effects on the habitats where plant and animal species live, as well as on plants, animals, and ecosystems that the U.S. Fish and Wildlife Service (USFWS) and corresponding State agencies specifically address as threatened, endangered, or otherwise deserving of special protection or consideration.

The ecological resource impact evaluation in this report examined whether activities in the alternatives could result in plant or wildlife habitat loss, direct vegetation or wildlife mortality, or disturbances (e.g., noise) affecting reproduction. For the generic, non-location-specific alternatives considered in this report, it was assumed that the impacts of any activities potentially affecting Federal or State special-status species or habitats would be avoided, minimized, or mitigated through appropriate actions determined in consultation with the USFWS and cognizant State agencies. The evaluation also assumes that air emission and water

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[15] Radiation dose, or simply dose, is a measure of the biological damage to an individual from ionizing radiation. Millisieverts (mSv) or millirem (mrem) are the units of measure of the effect ionizing radiation has on people. As a point of reference, the average annual background *dose* from natural sources of radiation received by a person in the U.S. is about 3.6 mSv (360 mrem).

discharge regulatory standards that are protective of human health would also be protective of ecological resources.

5.1.2.3 Historic and Cultural Resource Impacts

Historic and cultural resources may include prehistoric and historic archaeological sites, buildings, structures, districts, or other places or objects considered important to a culture or community for historical, traditional, religious, scientific, or other reasons. The evaluation of impacts on historic and cultural resources includes assessment of potential effects to these resources from activities conducted in the alternatives. Impacts would result if any of the following were to occur from these activities: damage to, or loss of, a site of archaeological, tribal, or historical value that is listed, or eligible for listing, on the National Register of Historic Places (NRHP); loss or degradation of a traditional cultural property or sacred site, or if the property or site is made inaccessible for future use; adverse effects to the qualities of a resource that render it eligible, as a historic property, for listing in the NRHP; or disturbance to any human remains, including those interred outside of formal cemeteries. For the generic, non-location-specific alternatives considered in this evaluation, the presence of such resources cannot be determined.

Because the six alternatives are assumed to be implemented at existing NPPs, LLRW processing facilities, and LLRW disposal facilities, and within the existing site boundaries and licensed scopes of operation, it is assumed that impacts to sensitive historic or cultural resources would be minimal. Where new activities are conducted, the impacts to sensitive historic and cultural resources would be minimized by their identification through cultural resource inventories and surveys, and subsequent avoidance, minimization, or mitigation of any potential impacts in accordance with the requirements of the National Historic Preservation Act (NHPA) Section 106 regulations (36 CFR Part 800) and through consultations with the State Historic Preservation Officers (SHPOs) and Tribal Historic Preservation Officers (THPOs), as appropriate.

5.1.2.4 Noise Impacts

Noise impacts could occur due to the potential effects of noise from project activities on the human and natural environment. Noise is sound that is undesirable because it interferes with speech, communication, or hearing; is intense enough to damage hearing; or is otherwise annoying.

The evaluation in this report examined whether activities conducted in the alternatives could result in noise impacts, and the relative magnitude of those impacts, if any. Potential noise impacts could result from any of the following: exceedance of applicable local, state, or Federal noise regulations or guidelines in the vicinity of sensitive receptors such as residences, hospitals, or schools; permanent increase of at least 10 decibels in ambient noise levels at the nearest sensitive receptors within the project vicinity; or exposure of persons to, or generation of, excessive ground-borne noise levels where people live, work, or participate in recreational activities. Impacts of noise on animal species and habitats were considered under ecological resource impacts.

5.1.2.5 Public and Occupational Health Impacts

Public and occupational health impacts could consist of the potential effects of project activities on public and worker health and safety. These impacts could result from public exposure to radioactive or hazardous constituents through inhalation, ingestion of water or food, or direct contact with water or soil; occupational injuries; or illnesses of workers who could be affected by radiological and non-radiological releases.

The evaluation in this report qualitatively examined how each alternative would contribute to public and worker health and safety risk. Radiological and non-radiological effects were evaluated separately for workers and the public. Impacts could result from any of the following: creation of worker health hazards beyond limits set by health and safety regulatory agencies (e.g., the Occupational Health and Safety Administration (OSHA)) or that endanger human life or property; serious injuries to workers, visitors, or nearby land users; changes in traffic patterns that result in hazardous situations for motorists or pedestrians; spills or releases of hazardous materials, hazardous substances, or petroleum products at or above reportable quantities within a project area that would pose a threat to public health or the environment in the project vicinity; or impaired implementation of, or physical interference with, an adopted emergency hazardous materials spill response plan or emergency evacuation plan. It is assumed that activities would comply with Federal, State, and local requirements to protect human health and safety (e.g., OSHA regulations in 29 CFR Part 1910).

Radiological and non-radiological impacts to public health from incident-free transportation and transportation accidents are addressed below under Transportation Impacts.

5.1.2.6 Soil Impacts

Impacts on soil could consist of contamination, or compaction or erosion of soils resulting in reduced productivity or significantly altered drainage characteristics. The soil impact evaluation in this report examined whether activities conducted in the alternatives could cause soil disturbance or contamination. It was assumed that these activities would comply with Federal, State, and local requirements (e.g., National Pollutant Discharge Elimination System (NPDES) requirements) to reduce, control, or avoid soil impacts.

5.1.2.7 Transportation Impacts

The analysis of potential transportation impacts in this report focuses entirely on the potential impacts of transportation of the spent IERs, primarily because the bulk of potential transportation impacts of the six alternatives would result from the shipment of these wastes. It is recognized that there would also be impacts resulting from transportation of operational workforces, raw materials, supplies, and incidental process wastes to and from the waste processing and disposal facilities. Transportation impacts related to the operations of the NPPs are not addressed because these impacts have already been assessed by the NRC in the environmental impact statements prepared in association with the licensing of these facilities.

Spent IER transportation activities for the various alternatives consist of the shipment of untreated or treated (processed) resins on public roadways in Type A and Type B shipping casks and return shipment of empty casks between the NPPs, waste processing facilities, and waste disposal facilities. The potential effects of routine transportation[16] of spent IERs and empty casks in the various alternatives on traffic volumes and patterns (e.g., traffic congestion) nationally and in areas local to the waste processing and waste disposal facilities are considered in the analysis. Routine transportation of radioactive materials could also affect air quality, noise, and road surface wear. Also, transporting radioactive and hazardous materials under any conditions could pose inherent risks and impacts to members of the public due to possible radiation exposure during routine transportation or as a result of transportation accidents. Facilities and transporters that handle radioactive materials must comply with regulatory requirements and have standard operating procedures (SOPs) in place to minimize these risks and protect worker and public health and safety. Note that exposures of “radiation workers” (e.g., truck crews, package handlers, and inspectors) are not considered in this analysis because these workers are specially trained in, and knowledgeable of, necessary radiation safety requirements and procedures, and are monitored and have radiation exposure limits stipulated by NRC regulation in 10 CFR 20.1201.

Three categories of potential transportation impacts were assessed in this evaluation, which represent the range of reasonable impacts to the public from the transportation of spent IERs (full and empty casks):

- Impacts of spent IER shipments on local traffic near centralized waste processing facilities and LLRW disposal facilities, and on total traffic in the U.S.;
- Radiological impacts to members of the public from routine, incident-free transport of spent IERs; and
- Non-radiological and radiological impacts to members of the public from transportation accidents involving spent IER shipments.

The transportation impact evaluation used quantitative information such as estimated numbers of shipments of full and empty Type A and Type B casks, quantities of waste transported in shipments, and trip lengths and population densities based on representative transportation routes. Results are correspondingly expressed quantitatively, although they are limited by the generic, non-location-specific nature of the six alternatives and, therefore, are also assessed qualitatively in this report.

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[16] Routine transportation takes place without incident. A transportation incident is any event that interferes with transportation between origin and destination. A transportation accident is an event that results in death, injury, or enough damage to an involved vehicle that the vehicle cannot move under its own power. All accidents are incidents.

The transportation analysis methodologies and assumptions are summarized below, and the analysis results are summarized in Table 5. This information is presented in detail in Appendix A. Note that, different from the other five alternatives, potential transportation impacts of Alternative 3 were evaluated for three separate time periods, or stages of this alternative (see Section 4.2.4): (1) “Years 1-20”, (2) “Year 21”, and (3) the period “After Year 21”. Also, for reasons detailed in Section A.2.3 and further discussed in Section A.3 of Appendix A, potential transportation impacts from the “Year 21” spent IER transportation scenario of Alternative 3 were estimated and reported in Appendix A for the sake of completeness only; and those potential impacts are neither summarized in the text nor in Table 5 of the main report nor are they discussed at any length in the detailed discussions of potential transportation impacts in Appendix A. To summarize, the Alternative 3 in Year 21 scenario is fundamentally a special case, or outlier, in relation to all of the other transportation scenarios evaluated for the six alternatives because potential impacts of this transportation scenario were substantially overestimated for justifiable purposes and, therefore, comparison of those impacts with those of the other alternatives would not be representative of actual practice. Note also that the potential transportation impacts of Alternative 3 in the period “After Year 21” were not separately estimated because those impacts would be identical to those of Alternative 2.

5.1.2.7.1 Impacts on Local and National Traffic

The evaluation examined the potential effects on local and national traffic caused by the transportation of the spent IERs (full and empty casks) in each alternative.

Impacts on Local Traffic

Potential impacts on local traffic near spent IER processing facilities (for blending or volume reduction) and LLRW disposal facilities, from trucks carrying spent IERs and empty shipping casks, were evaluated using estimated numbers of annual truck shipments for each alternative (see Table A-2 in Section A.2.3 of Appendix A). Trucks would enter and leave these facilities only during their normal working hours. Thus, for this analysis, the annual numbers of shipments (trips) for each of the alternatives were divided by the number of operating hours per year for a waste processing or disposal facility (assumed to be 2000 hours per year, based on fifty 40-hour work weeks), to obtain an average number of trucks per hour on local roads entering and leaving these facilities.

Impacts on National Traffic

Potential traffic impacts on a national level were evaluated by comparing the estimated annual weight of spent IER shipments (full and empty casks) in each alternative to the total annual U.S. truck freight weight carried by tractor-trailer trucks, expressed as a percentage. The USDOT Bureau of Transportation Statistics estimates the freight transported annually by heavy trucks in the U.S. at 1.13×10^{10} metric tons per year (1.25×10^{10} tons per year) (USDOT, 2011). For the purposes of this evaluation, the full and empty cask weights for each cask type were conservatively assumed to be the same.

5.1.2.7.2 Radiological Impacts of Routine Transportation

Potential radiological impacts from routine, incident-free transportation of spent IERs in Type A and Type B shipping casks were evaluated for individual receptors and for populations, for various scenarios involving moving and stationary trucks. Individual receptors are persons at various locations along transportation routes traveled by trucks carrying radioactive materials (e.g., spent IERs from NPPs). Populations are groups of residents along the transportation routes. During routine transportation, external radiation from the shipping casks used to transport radioactive materials, such as the spent IERS from NPPs, is the source of the radiation dose to the various potential receptors. In this evaluation, potential radiological impacts due to possible exposures of various individual human receptors to this external radiation, in terms of doses of radiation in mSv (or mrem), are estimated using the RADTRAN 6 model (Weiner et al., 2009) (hereafter called the “RADTRAN model” or “RADTRAN”). For a radiation dose to a population, RADTRAN calculates the “collective dose” (expressed in units of person-mSv[17]), by integrating the average radiation dose over the area occupied by the population. RADTRAN is the nationally accepted, standard computer program for calculating the risks of transporting radioactive materials.

In modeling radiological impacts from routine transportation, RADTRAN models the external radiation dose rate[18] from the shipping cask as if the radiation were emitted from a point source located where the center of the cask would be. When the actual external radiation dose rate from the shipping cask is not specifically known, as is the case for the Type A and Type B shipping casks containing spent IERs in this evaluation, the maximum external dose rate for a shipping cask allowed by NRC regulation is used in RADTRAN to assess radiation doses to individuals and populations. NRC regulations allow shipping containers, or casks, that hold radioactive materials to emit minor amounts of ionizing radiation from the external cask surfaces. The Type A and Type B casks used to transport spent IERs, as all containers certified for use to transport radioactive materials, must meet the NRC standard for external radiation during normal transport. In the case of flat-bed style trucks such as those used to transport casks of spent IERs, by NRC regulation in 10 CFR 71.47(b)(3), the dose rate from this external radiation must not exceed 0.1 mSv per hour (10 mrem per hour) at a distance of 2 meters (m) (6.6 feet (ft)) from the vertical planes projected by the outer edges of the trailer carrying the cask. Basing the RADTRAN modeling on this maximum, legally allowable dose rate is conservative because actual dose rates from shipping casks would generally be much lower than the allowable limit.

The radiation doses from the various alternatives are estimated based on annual numbers of spent IER shipments; therefore, these estimated doses are the doses from exposures over a period of one year. Thus, to put the annual doses to individuals in perspective, they are

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[17] Person-mSv is a unit of dose that represents an individual dose integrated over an area that is occupied by a population. It can be thought of as an average individual dose multiplied by the number of people over which it is averaged.

[18] Radiation dose rate, or dose rate, is the radiation dose per unit time, expressed as millisieverts (mSv) per hour (or millirem (mrem) per hour).

compared with the average annual U.S. background dose of 3.6 mSv/year (360 mrem/year) (Shleien et al., 1998), as a percentage of this background dose. For populations, the annual collective dose[19] is compared to 3.6 mSv/year (360 mrem/year) multiplied by the affected population, since each member of the population sustains this annual average background dose. The use of the annual U.S. background radiation level allows for the assumption that the background level would be the same for all receptors. Also, from the estimated radiation doses, the corresponding probabilities of fatal cancers resulting from exposure to these radiation doses, or latent cancer fatalities (LCFs), are derived. Specifically, LCFs are the expected number of additional cancer fatalities that may occur during the lifetime of individuals, because of (or latent to) an exposure to ionizing radiation. LCF values are derived by multiplying the dose by a conversion factor, 6×10^{-5} LCF per mSv (ISCORS, 2002). The calculated LCFs are also expressed as a fraction (percentage) of 2010 estimated total cancer fatalities in the U.S. of 569,495 (American Cancer Society, 2010).[20]

Impacts on Individual Receptors

Potential radiological impacts are calculated using RADTRAN for the following types of individual receptors:

- Individual maximally exposed to a moving truck (maximally exposed individual, or MEI)
- Average person along the transportation route: rural–suburban
- Average person along the transportation route: urban
- Average resident near a truck stop: rural–suburban[21]

The MEI shown above is the individual receiving the maximum exposure to a moving truck carrying a radioactive cargo. The MEI is modeled as a person standing as close as possible (30 m from the center of the highway) to the moving truck, when the truck is moving slowly (about 24 kilometers per hour (kph) (15 miles per hour (mph)) past the MEI.

Potential radiological impacts to individuals (radiation doses) calculated using RADTRAN were first estimated for one routine shipment of spent IERs of each cask type (full casks). The results of those calculations were then used to estimate the potential radiological impacts to individuals from all routine shipments per year for each of the six alternatives. Return trips were not modeled because there would be negligible or no radiological impacts from routine shipments of empty casks. The total annual dose for each alternative, for the various types of individual receptors, were calculated by multiplying the dose from a single shipment by the annual number of shipments carrying spent IERs (full casks). This approach is based on the conservative

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[19] See Section A.3.2.2 for definition of collective dose.

[20] 2010 total estimated cancer fatalities in the U.S. derived by the American Cancer Society from U.S. mortality data, 1969-2007.

[21] Truck stops would be for rest and refueling. Truck stops are not modeled in urban areas because stops used by trucks carrying radioactive materials would generally be away from heavily populated areas.

assumptions that (1) each individual receptor is exposed to every spent IER shipment for a given alternative[22], and (2) the doses from exposures to multiple shipments are additive[23]. Thus, actual exposures would be lower than are estimated in this evaluation. LCFs were calculated from the radiation doses as discussed earlier.

Impacts on Populations

Potential radiological impacts, in terms of collective doses, from routine spent IER shipments (full casks) on populations were also estimated. For the six alternatives considered in this evaluation, the transportation routes would be between NPPs and waste processing facilities (for blending or volume reduction), between NPPs and LLRW disposal facilities, and between waste processing facilities and LLRW disposal facilities.

The RADTRAN calculation of collective (population) dose required identification of specific transportation origins and destinations, and data on the route miles and populations and population densities for the transportation routes between these origins and destinations. For this analysis, a number of "representative" origins and destinations were identified for use in the modeling. These were selected to be representative of origins of untreated or treated (processed) spent IERs and destinations for spent IER processing or disposal. The representative origins and destinations selected, although generally based on actual, existing facility locations, were used for illustrative purposes only for calculating potential radiological impacts on populations; they were not meant to designate actual spent IER shipment origins and destinations for the six alternatives because actual routes cannot be identified for generic, non-location-specific alternatives such as those considered in this evaluation.

TRAnsportation Geographic Information System, the routing code maintained by Oak Ridge National Laboratory (Johnson and Michelhaugh, 2003), is typically used to provide transportation route parameters for use in RADTRAN. However, for this evaluation, the choice of representative origins and destinations and corresponding transportation routes between them was severely constrained because TRAGIS is shut down and unavailable for an undetermined time period (Johnson, 2011). TRAGIS, when available, provides the most recent census data of population densities along routes, a listing of every road and every intersection by highway route number, and the rural, suburban, and urban fractions of the total routes through each state. Thus, since TRAGIS was not available, representative transportation origins and destinations and corresponding transportation routing data were constructed from, and limited by, the availability of relevant information on transportation routes in the library of TRAGIS routings maintained by SNL. Within these constraints, transportation origins and destinations were selected to allow for the analysis of potential radiological impacts to populations along a range of transportation routes spanning the U.S. Potential radiological

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[22] In actual practice, this would not occur since not all individuals would be located in the same place at the same time over a period of one year.

[23] In reality, multiple radiation doses over time are not additive. For example, in calculating medical therapeutic and diagnostic doses, the patient's prior history of radiation exposure is not usually considered or summed (Shleien et al., 1998; Chapter 10).

impacts on populations from routine transportation were separately estimated for moving trucks and for trucks at rest and refueling stops.

- Impacts from Moving Trucks. Potential radiological impacts to populations from routine, incident-free movement of spent IER shipments along transportation routes defined by representative origins and destinations were estimated for each alternative. The collective dose from a spent IER shipment (full cask) for each representative transportation route was calculated as the sum of the collective doses for the rural, suburban, and urban route segments in all of the states traversed on the route. This summed result was multiplied by the number of spent IER shipments (full casks) per alternative to obtain the total collective doses for each of the six alternatives.

- Impacts from Trucks at Rest and Refueling Stops. Truck stops that serve the 18-wheel tractor-trailer trucks that carry Type A or Type B casks containing spent IERs would mostly be located in rural or suburban areas near freeway access ramps. Each truck stop is surrounded by a different resident population. The analysis conservatively assumed that the resident population at each truck stop would be exposed to all of the shipments in each alternative. Potential radiological impacts to populations residing near the truck stops were estimated for each alternative based on such factors as numbers of truck stops on each representative transportation route, population densities near the truck stops in rural and suburban setting along these routes, sizes of areas where potentially affected populations would reside, previously estimated individual external doses, and numbers of spent IER shipments (full casks) by alternative.

5.1.2.7.3 Non-radiological and Radiological Impacts of Transportation Accidents

Trucks carrying spent IERs or empty casks are as likely to be involved in traffic accidents as any other similar heavy trucks. Potential non-radiological and radiological impacts of transportation accidents as a result of traffic collisions involving trucks carrying spent IER shipments were evaluated. Non-radiological impacts of transportation accidents were measured in terms of the number of traffic accidents and the number of traffic accident fatalities from the transport of both full and empty casks. Radiological impacts were assessed from traffic accidents in involving trucks carrying full shipping casks of spent IERs, under scenarios in which radioactive materials are and are not released from the casks.

Non-radiological Impacts

In this evaluation, non-radiological impacts of transportation accidents were assessed in terms of the estimated number of traffic accidents and number of traffic accident fatalities from shipments of spent IERs in each alternative. These potential impacts were estimated using tractor-trailer truck traffic accident and accident fatality rate information (adapted from 2009 USDOT (2010; 2011) state and national transportation statistics, the most recent data available), coupled with the total distances driven under each alternative with full and empty casks. To put the estimated potential non-radiological impacts in perspective, the annual numbers of potential truck accidents and associated traffic accident fatalities for each alternative were compared with the annual total numbers of tractor-trailer truck accidents and accident fatalities in the U.S., respectively, as reported by USDOT (2011).

Radiological Impacts

The potential radiological impacts (consequences) of two types of transportation accidents involving the transport of untreated and treated (processed) spent IERs in Type A and Type B shipping casks (full casks) were evaluated: (1) accidents in which there is no impact on the cask and, therefore, no release of radioactive material; and (2) accidents in which there is an impact on the cask, and radioactive material could be released. The distinction between the two types of accidents is made because more than 91 percent of all accidents involving trucks carrying radioactive material and more than 99 percent of accidents involving Type B casks do not result in any damage to the cargo and therefore would not involve a release of radioactive material (NRC, 1977; Table 5-3; Sprung, et al, 2000; Chapter 7, pp. 7-73 to 7-76).

- Accidents with No Release of Radioactive Materials. For accidents in which there is no impact on the shipping cask, the collective radiation dose and corresponding LCF are calculated using RADTRAN for all representative transportation routes and alternatives. The dose to the nearest member of the public (the MEI) and corresponding LCF are also calculated, which would be the same regardless of transportation route, accident location, or alternative. In addition to comparing the collective LCFs with 2010 total estimated U.S. cancer fatalities, they are measured against the potential traffic fatality risks from spent IER shipments for the same routes and alternatives (i.e., the non-radiological impacts of traffic accidents from above) to compare predicted cancer deaths from radiological exposures to truck accident-related fatalities from non-radiological causes. Since no radioactive materials would be released, exposure would be from the external radiation from the casks; and the analysis is conservatively based on the legally-defined maximum external dose rates from the Type A and Type B casks, which are the same for both cask types (see Section 5.1.2.7.2). In actual practice, the external dose rates from these casks would probably be lower. Further, the modeling is conducted based on a suburban truck stop because that is more conservative than modeling for a rural truck stop (due to higher populations near suburban truck stops). However, the time at the accident location would be longer than at a normal truck rest and refueling stop because the accident may require removal of the cask, either by transferring it by crane to another vehicle or by removing the truck and cask from the accident scene. Considering the size and weight of the full casks (see Table A-1 in Appendix A), it could take several hours to bring appropriate equipment for this purpose to the accident location; and 10 hours is assumed for the RADTRAN assessment.

- Accidents in Which Radioactive Material Could Be Released. The analysis separately examined the consequences of accidents involving Type A and Type B casks in which radioactive material could be released. Due to design differences between these two types of shipping casks and the different classes of waste they would carry, the consequences of accidents involving these two cask types would be different. Type A casks are the least robust in design of the two and, therefore, more likely to be damaged in an accident, but would carry the lower activity Class A spent IERs. Type B casks, which would carry the higher activity Class B and C resins, are very robust and designed to withstand severe accidents. Accident consequences were examined separately for accidents involving spent IERs from BWRs and PWRs because the radionuclide inventories from these two sources could be different and the public would exposed to the actual radionuclide inventory.[24] Note also that accident consequences for each cask type are evaluated for a single accident of each kind and not for each of the six alternatives. This is because, as illustrated in Section A.3.3.1 of Appendix A, the numbers of tractor-trailer truck accidents that occur is extremely low, and the likelihood of even one such accident occurring is extremely small.

- *Accidents in Which a Type A Cask Would Be Impacted*—For Type A casks, the analysis examined the potential impact on members of the public if a cask of this type is in an accident that is severe enough to damage and expose the public to the entire spent IER contents of the cask. The radionuclide inventory that can be carried in a Type A cask is limited by regulation; specifically, the radionuclide inventory than can be transported in a Type A cask cannot not exceed the A_2 value defined in 10 CFR 71, Appendix A, Table A-1. The A_2 values were calculated using the “Q system” defined by the International Atomic Energy Agency (IAEA, 2002b; Appendix I, Section I.11, pp. 216 et seq.), which is based on a set of exposure scenarios called the “Q series”. The Q system defines the quantity limits of radionuclides (e.g., in terms of A_2 values) that are allowed in a Type A package. The present analysis uses the Q system to define the basis for exposure to a release of spent IERs from a Type A cask severely damaged in a transportation accident. The IAEA Q system is based on a person exposed to an A_2 quantity of radioactive material receiving a radiation dose no greater than 50 mSv (5000 mrem) if that person is located one meter from the A_2 quantity for 30 minutes. Thus, if a Type A cask carrying an A_2 quantity of material is in an accident so severe that a person standing one meter from the cask is exposed to the entire contents of the cask for 30 minutes, he or she would receive a dose of ionizing radiation that is at most 50 mSv. This information was used to calculate the dose to a receptor at a specific distance from the source (e.g., the A_2 amount potentially released from a damaged Type A cask in an accident) for a specific period of time. Radiation dose is inversely proportional to the square of the distance of the receptor from the radiation source and directly proportional to the amount of the receptor time spends at that distance. The dose to a receptor is also directly proportional to the total radioactivity to which the receptor is exposed.

- *Accidents in Which a Type B Cask May Be Impacted*—Spent IERs that exceed the A_2 limit must be carried in Type B casks. Type B casks are designed to be

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[24] Radionuclide inventory is the list of radionuclides in a particular material and the activity of each, expressed in curies.

sufficiently robust that they are not likely to be damaged in a traffic accident (10 CFR 71.73). Release of radioactive material from a Type B cask could occur only in accidents considerably worse than almost all traffic accidents. Such accidents would involve extremely severe impacts of casks onto hard targets, or a very long-lasting, very hot fire, or both. Even such extreme conditions would not damage the body of the cask, and releases of radioactive material, if any, could occur only through the cask seals and then only in very small quantities (Sprung et al., 2000; Chapters 7 and 8). Thus, the only way in which spent IER material released from a Type B cask could result in a radiation dose to a member of the public is if the material could be dispersed from damaged cask seals as very small, aerosol-sized particles. From among the six alternatives, the only spent IERs that could potentially be released through damaged Type B cask seals as aerosolized particles could be those that are thermally processed (blended or volume-reduced) and transported to a waste disposal site in Alternatives 1B, 4A, and 4B. These thermally processed resins would be the only materials to be transported that would be dry (water free) and in powdery, small particle form that might be aerosolized.

There is no published model for the accidental release of spent IERs, or similar LLRW, in aerosolized form from damaged seals of a Type B cask. The only current published model of such releases of radioactive material from a Type B cask is that of potential release of NPP spent nuclear fuel particles and of corrosion products that are on the outer surface of SNF elements (Sprung et al., 2000; Chapter 7). This model was adapted for in this analysis and used in association with the RADTRAN accident model to assess potential radiological impacts of spent IER releases from Type B casks.[25] Following the practice first used by the NRC in NUREG-0170, "Final Environmental Impact Statement for the Transportation of Radioactive Material by Air and Other Modes" (NRC, 1977), and used subsequently in other environmental impact assessments and studies of this type (Fischer et al., 1987; Sprung, et al, 2000; DOE, 2002, Appendix J), six different types of accidents, of varying severity and a range of release fractions[26], were postulated in this analysis. These accident scenarios are intended to include most of the extremely severe transportation-related accidents possible (DOE, 2002, Appendix J). The RADTRAN accident analysis was conducted only for the most severe accident scenario (truck fire exposing the cask with high-speed impact into hard target) because that is the scenario with

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[25] It is important to note that although there may be certain physical similarities between thermally processed spent IERs and spent nuclear fuel (SNF) particles and corrosion products that allow us to apply this model in this case, the radioactivity levels of the Class A, B, and C LLRW spent IERs are orders of magnitude lower than that of SNF materials. For example, Cesium-137 (Cs-137) is present in SNF in concentrations on the order of 10^5 Ci per fuel assembly (DOE, 2002; Appendix A, Tables A-8 and A-9), whereas the Ci content of Cs-137 in a spent IER shipment in a Type B cask would be about one curie or less and the total curie content in a Type B cask carrying BWR Class B and C resins would be about 52 Ci (see Table A-21, Section A.3.3.2.2 of Appendix A).

[26] Release fraction is the fraction of total radioactivity in the cask released for a particular accident scenario.

the highest release fraction of the six and, therefore, would yield the most conservative impact analysis results.

5.1.2.8 Waste Management

Waste management impacts could consist of the effects of generation, management, storage, and preparation for offsite disposal of wastes on safety, regulatory compliance, or waste storage, treatment, and disposal capacities. Wastes generated in performance of activities in each of the six alternatives may include radioactive, hazardous, mixed radioactive and hazardous, and nonhazardous solid waste, and process wastewater. The handling and disposal of waste materials are governed by various Federal, State, and local regulations. Waste management programs in place at operating facilities are generally intended to minimize the generation of waste through reduction, reuse, and recycling, and include systems and procedures for the collection, removal, and proper disposal of waste materials.

The waste management evaluation in this report examined how each component activity of each of the alternatives could add to or alter existing waste and materials management operations (e.g., land disposal facilities). Adverse impacts would result from reduction of physical safety, non-adherence to regulatory requirements, or significant reduction of waste storage, treatment, or disposal capacities.

Note that the analysis of waste management impacts in this report specifically addresses wastes that are “incidental” to the management of spent IERs, as impacts from the management of spent IERs are the focus of this entire evaluation. As discussed in Section 2.1.3, the commercial NPP spent IERs themselves account for only about 4 percent of the total volume of commercial LLRW generated in the U.S. annually and, therefore, disposal of these wastes would have a relatively small impact on U.S. LLRW disposal capacity.

5.1.2.9 Water Resources

Impacts on water resources could consist of the potential effects on the groundwater and the surface water system at and in the vicinity of a project or facility. Adverse effects could include degradation of water quality and reduction of water supply.

The evaluation of water resource impacts in this report assessed the potential effects on groundwater and surface water quality and water supply (water use). This evaluation considered activities that could degrade groundwater or surface water quality, alter drainage patterns, or change the quantity of groundwater or surface water resulting in altered water table or surface water body characteristics and water supply availability.

5.1.3 Mitigation Measures for Potential Environmental Impacts

As discussed in Section 3.2, the analytical approach also includes consideration of whether generally accepted impact mitigation measures could reduce adverse environmental impacts in the various resource and impact areas, and accounts for applicable mitigation measures in assessing potential impacts. Examples of typical impact mitigation measures that could be implemented are listed in Table 4 for each resource or impact area.

Since this evaluation focuses mainly on the impacts of operations at existing facilities, many of the mitigation measures listed in Table 4 relate to operations at the NPPs, spent IER processing facilities, long-term spent IER storage facilities, or LLRW disposal facilities, although some of the measures listed would apply to mitigation of impacts during construction of long-term spent IER storage facilities (Alternatives 3 and 4A) and for transportation of untreated and treated (processed) spent IERs. Also, as discussed in Section 3.2, it is assumed for the purposes of this evaluation that all activities in the six alternatives would be in compliance with applicable Federal, State, and local legal and regulatory requirements. This means that all necessary equipment and procedures would be in place for licensed or permitted activities at all of the NPPs and spent IER storage, processing, and disposal facilities, and during shipment of spent IERs between these facilities, for protection of human health and the environment. The actual mitigation measures and regulatory controls employed would vary depending upon the activities and processes at specific geographic locations and in specific environmental settings, and based on factors such as feasibility of implementation, effectiveness, reliability, and cost.

5.1.4 Evaluation of Potential Impacts

Potential environmental impacts of the six alternatives are described and compared in Table 5. The environmental impact assessments are presented in tabular format to facilitate a concise discussion and comparison of potential impacts of the alternatives in each resource or impact area.

As discussed in Section 3.2, the assessment of potential impacts in this evaluation is qualitative, except for the assessment of transportation impacts, which is largely quantitative. Further, with the exception of transportation-related accidents, impacts of accidents and other off-normal conditions are not considered, for reasons discussed in Section 3.3. Other resource and impact areas not included in the impact evaluation in Table 4 are also identified in Section 3.3. Note also that, as discussed in Section 3.2, the six alternatives are assumed to be implemented at existing NPPs, spent IER processing facilities, and LLRW disposal facilities, and within existing facility footprints and site boundaries and licensed and permitted scopes of operations at those facilities.

Note also that as discussed earlier, conservative, often bounding assumptions are made throughout the evaluation, consistent with the generic, non-location-specific alternatives evaluated. Thus, in actual practice, any potential environmental effects associated with the six alternatives would, for the most part, be expected to be somewhat lower in magnitude than those described in this report.

Section 5.2 (Summary and Discussion of Comparative Environmental Evaluation) follows Tables 4 and 5 below.

Table 4 Examples of Typical Mitigation Measures for Potential Environmental Impacts of Component Activities Comprising the Six Alternatives for Handling LLRW Spent Ion Exchange Resins

RESOURCE OR IMPACT AREA	MITIGATION MEASURES	APPLIES TO:				
		Processing Facility Operations	**Waste Storage Facility Construction**	**Waste Storage Facility Operations**	**Waste Transportation**	**Waste Disposal**
Air Quality	Maintenance of internal combustion engines and their pollution control devices in good working order	X	X		X	X
	Use of engineered controls to minimize radiological and non-radiological air emissions or concentrations (e.g., off-gas systems, HEPA filters, air handling systems, containment)	X			X	X
	Prompt cleanup of all spilled materials	X	X	X	X	X
	Watering of soils to control fugitive dust		X			X
Ecological Resources	Use of native plant species to re-vegetate disturbed areas and enhance wildlife habitat		X			X
	Implementation of recommendations of Federal and State natural resource agencies, e.g., USFWS		X			X
	Scheduling of construction activities to minimize disturbance to protected wildlife species		X			X

Table 4 Examples of Typical Mitigation Measures for Potential Environmental Impacts of Component Activities Comprising the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	MITIGATION MEASURES	APPLIES TO:				
		Processing Facility Operations	**Waste Storage Facility Construction**	**Waste Storage Facility Operations**	**Waste Transportation**	**Waste Disposal**
Historic and Cultural Resources	Training of workers on the regulations governing protection of cultural resources		X			X
	Use of onsite cultural resource monitors during ground disturbing activities		X			X
	Implementation of procedures to address unexpected discoveries of archaeological materials and human remains		X			X
	Development of specific mitigation measures in the event of discovery of resources eligible for listing on the National Register of Historic Places (e.g., professional excavation and data recovery)		X			X
Noise	Use of engineered and administrative controls for equipment noise abatement (e.g., equipment and vehicle mufflers, acoustic baffles, shrouding, barriers, noise blankets)	X	X	X	X	X
	Mitigation of operational noise sources by facility design, whereby cooling systems, valves, transformers, pumps, generators, and other equipment are located mostly within plant structures and the buildings absorb or contain the majority of the noise	X				
	Establish preventative maintenance programs that ensure all equipment is working at peak performance	X	X		X	X

Table 4 Examples of Typical Mitigation Measures for Potential Environmental Impacts of Component Activities Comprising the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	MITIGATION MEASURES	APPLIES TO:				
		Processing Facility Operations	**Waste Storage Facility Construction**	**Waste Storage Facility Operations**	**Waste Transportation**	**Waste Disposal**
Public and Occupational Health	Facility design features to minimize gaseous and liquid effluent releases, and maintain the impacts to workers and surrounding populations below regulatory limits	X		X		X
	Use of administrative controls, practices, and procedures (including training) to ensure compliance with an established Health, Safety, and Environmental Program	X	X	X	X	X
	Implementation of radiological practices and procedures to achieve and maintain radiological exposure to levels that are as low as reasonably achievable (ALARA)	X	X	X	X	X
	Conduct of routine facility radiation and radiological surveys to characterize and minimize potential radiological dose and exposure	X	X	X		X
	Monitoring of all radiation workers by use of dosimeters and area air sampling to ensure that radiological doses remain within regulatory limits and are ALARA	X	X	X	X	X
	Environmental surveillance to ensure public safety	X	X	X		X
	Implementation of other maintenance and monitoring procedures, as applicable.	X	X	X		X

Table 4 Examples of Typical Mitigation Measures for Potential Environmental Impacts of Component Activities Comprising the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	MITIGATION MEASURES	APPLIES TO:				
		Processing Facility Operations	**Waste Storage Facility Construction**	**Waste Storage Facility Operations**	**Waste Transportation**	**Waste Disposal**
Soil	Follow requirements of Spill Prevention Control and Countermeasures (SPCC) Plan to reduce the potential impacts from chemical spills or releases	X	X	X		X
	Follow waste management procedures to minimize impacts on soils from solid waste and hazardous materials	X	X	X	X	X
	Implementation of soil sampling program to check for deposition of contaminants released from the facility via airborne pathways	X				X
	Use of best management practices (BMPs) to reduce soil erosion (e.g., earth berms, dikes, sediment fences)		X			X
	Re-vegetate or cover bare areas with natural materials promptly		X			
	Reuse excavated materials whenever possible		X			X
Transportation	Scheduling of waste and return shipments to minimize impacts on local roadways				X	
	Perform regular vehicle inspections				X	
	Adhere to all regulatory requirements related to transportation of radioactive and hazardous materials				X	

Table 4 Examples of Typical Mitigation Measures for Potential Environmental Impacts of Component Activities Comprising the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	MITIGATION MEASURES	APPLIES TO:				
		Processing Facility Operations	Waste Storage Facility Construction	Waste Storage Facility Operations	Waste Transportation	Waste Disposal
Waste Management	Design and implementation of system features and practices to minimize generation of solid waste, liquid waste, and gaseous effluent	X	X	X		
	Storage of waste only in designated areas of the facility	X	X	X		X
	Shipment of incidental waste offsite to licensed disposal facilities	X	X	X		
	Control of process effluents by careful application of basic principles for waste handling in all systems and processes	X				
	Segregation of different waste types in separate containers to minimize contamination of one waste type with another	X	X			X
	Administrative procedures and practices in waste management systems that provide for collection, temporary storage, processing, and disposal in accordance with BMPs and regulatory requirements	X	X	X		X

Table 4 Examples of Typical Mitigation Measures for Potential Environmental Impacts of Component Activities Comprising the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	MITIGATION MEASURES	APPLIES TO:				
		Processing Facility Operations	Waste Storage Facility Construction	Waste Storage Facility Operations	Waste Transportation	Waste Disposal
Water Resources	Use of low-water consumption practices	X	X			X
	Incorporation of closed-loop cooling systems eliminating evaporative losses	X				
	Employing BMPs to control the use of hazardous materials and fuels	X	X	X	X	X
	Control and mitigation of spills in conformance with SPCC plans	X	X	X		X
	Ensure all discharges meet the standards for stormwater management	X	X	X		X
	Handle any hazardous materials by approved methods and ship offsite to approved disposal sites	X	X	X		X

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	**ALTERNATIVE 1B** DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	**ALTERNATIVE 2** DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	**ALTERNATIVE 3** LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]	**ALTERNATIVE 4A** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]	**ALTERNATIVE 4B** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]
AIR QUALITY: ***Radiological***	SMALL. Minimal or no radioactive air emissions and associated impacts would be expected during handling, transport, and disposal of spent ion exchange resins (IERs), primarily because of safety procedures implemented during these activities and the types of waste containers, shipping casks, and disposal methods used. There would be source radioactive air emissions from the mechanical mixing (blending) process, but these emissions would be within regulatory limits because stack emissions must comply with the National Emissions Standards for Hazardous air Pollutants (NESHAPs) and other permit or license requirements, with emissions controls employed as necessary. Note also that these emissions would be expected to be less than those from the thermal	SMALL. Radiological air emissions impacts during spent IER handling, transport, and disposal would be similar to those described for Alternative 1A. There would be source radioactive air emissions from blending by thermal processing, which would be expected to be somewhat greater than those from blending by mechanical mixing (Alternative 1A) due to increased volatilization in the thermal (heating) process. However, emissions controls would be employed to maintain compliance with NESHAPs and other permit or license requirements.	SMALL. Radiological air emissions impacts during spent IER handling, transport, and disposal would be similar to those described for Alternative 1A. This alternative involves no waste processing and associated radiological air emissions.	SMALL. Radiological air emissions impacts during spent IER handling, transport, and disposal would be similar to those described for Alternative 1A. This alternative involves no waste processing and associated radiological air emissions. There would be no radiological air emissions resulting from construction of the onsite long-term spent IER storage areas at the 65 nuclear power plants (NPPs) because no radioactive materials would be used during construction. Maintenance and monitoring of these storage facilities, when in use, would serve to minimize any radiological air emissions.	SMALL. Radiological air emission impacts during spent IER handling, transport, thermal processing (volume reduction), and disposal would be similar to those described for Alternative 1B because these alternatives employ similar thermal processing technologies, and all other component activities of the two alternatives would be essentially the same. There would be no radiological air emissions resulting from construction of the onsite long-term spent IER storage area at the waste disposal site because no radioactive materials would be used during construction. Maintenance and monitoring of the storage facility, when in use, and the stabilized nature of the waste form in storage, would serve to minimize any radiological air emissions.	SMALL. Radiological air emissions during spent IER handling, transport, thermal processing (volume reduction), and disposal would be similar to those described for Alternative 1B because these alternatives employ similar thermal processing technologies, and all other component activities of the two alternatives would be essentially the same.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
AIR QUALITY: ***Radiological (Cont.)***	processing alternatives (1B, 4A, and 4B) that involve heating of the spent IERs and resulting increased volatilization.					
AIR QUALITY: ***Non-radiological*** *(NOTE: Non-radiological air quality impacts associated with the transport of spent IERs are addressed later in this table, under Transportation: Local and National Traffic.)*	SMALL. Minor impacts from emissions of non-radiological air pollutants would result from equipment usage for spent IER handling at the NPPs and the mechanical mixing (blending) and disposal facilities, as exhaust concentrations must comply with National Ambient Air Quality Standards (NAAQS), NESHAPs, Occupational Safety and Health Administration (OSHA), and other permit or license requirements. Emissions controls and other measures would be used to minimize air emissions from this equipment. Non-radiological air emissions from the mechanical mixing	SMALL. Non-radiological air emissions impacts during spent IER handling, and disposal would be similar to those described for Alternative 1A. There would be non-radiological air emissions from blending by thermal processing, which would be expected to be somewhat greater than those from blending by mechanical mixing (Alternative 1A) due to increased volatilization in the thermal (heating) process. Filtration systems would be	SMALL. Non-radiological air emissions impacts during spent IER handling, and disposal would be similar to those described for Alternative 1A. This alternative involves no waste processing and associated non-radiological air emissions.	SMALL. Non-radiological air emissions impacts during spent IER handling, and disposal would be similar to those described for Alternative 1A. This alternative involves no waste processing and associated non-radiological air emissions. Construction of small, onsite facilities for long-term storage of spent IERs would take place at 65 NPPs, at geographically dispersed locations nationwide. At each NPP, impacts from construction equipment emissions (i.e., vehicle exhaust) on air quality and worker and public health would be minor because exhaust concentrations would comply with NAAQS,	SMALL. Non-radiological air emissions impacts during spent IER handling, thermal processing (volume reduction), and disposal would be similar to those described for Alternative 1B because these alternatives employ similar thermal processing technologies, and all other component activities of the two alternatives would be essentially the same. Construction of a relatively small, long-term spent IER storage facility at the waste disposal site would be required. Impacts from construction equipment emissions on air quality and worker and public health would be minor because exhaust concentrations would	SMALL. Impacts of air emissions during waste handling, thermal processing (volume reduction), and disposal would be similar to those described for Alternative 1B because these alternatives employ similar thermal processing technologies, and all other component activities of the two alternatives would be essentially the same.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	**ALTERNATIVE 1B** DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	**ALTERNATIVE 2** DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	**ALTERNATIVE 3** LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]	**ALTERNATIVE 4A** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]	**ALTERNATIVE 4B** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]
AIR QUALITY: ***Non-radiological (Cont.)***	(blending) process equipment would be minor because the blending process is conducted at ambient temperatures, and any emissions must comply with NAAQS, NESHAPs, and other permit or license requirements, with emissions controls employed as necessary. Note also that these emissions would be expected to be less than those from the thermal processing alternatives (1B, 4A, and 4B) that involve heating of the spent IERs and resulting increased volatilization. Best management practices (BMPs) would be employed to minimize fugitive dust generation during spent IER disposal operations at the LLRW disposal facility.	employed at the thermal processing facility to control air emissions, and stack emissions must comply with NAAQS, NESHAPs, and other permit or license requirements.		NESHAPs, OSHA, and other permit or license requirements. Emissions controls and other measures would be employed to minimize air emissions from the equipment. BMPs would be used to minimize fugitive dust generation. Any impacts would be temporary and intermittent in nature over the short duration of construction of the small storage facilities. Also, construction activities would comply with applicable license and permit requirements. For the most part, since the 65 NPPs are located in separate regions of influence (ROIs) for air emissions, construction of the storage facilities generally would not result in cumulative air quality impacts due to construction of multiple storage facilities in the same air quality ROI.	comply with NAAQS, NESHAPs, OSHA, and other permit or license requirements. Emissions controls and other measures would be employed to minimize air emissions from the equipment. BMPs would be used to minimize fugitive dust generation. Any impacts would be temporary and intermittent in nature over the relatively short duration of construction of the spent IER storage area. Also, construction activities would comply with applicable license and permit requirements. Since it is likely that this waste storage facility would be constructed in increments (stages) rather than all at once, air quality impacts at each stage would be smaller than those for construction of the entire storage facility at one time.	

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
AIR QUALITY: ***Non-radiological (Cont.)***				Maintenance and monitoring of the long-term spent IER storage facilities, when in use at the 65 NPPs, would serve to minimize any non-radiological air emissions.	Maintenance and monitoring of the long-term spent IER storage facility, when in use at the waste disposal site, and the stabilized nature of the waste form, would serve to minimize any non-radiological air emissions.	
ECOLOGICAL RESOURCES	SMALL. The existing NPPs and mechanical mixing (blending) and disposal facilities would operate within existing facility footprints. There would be little or no additional ground disturbance or other activities during spent IER handling and processing and none during spent IER transport. Thus, impacts on wildlife and plants from these operations would be minimal. Any air emissions and wastewater discharges would be within regulatory limits, and noise mitigation measures would keep	SMALL. Impacts to ecological resources from spent IER handling, thermal processing (blending), transport, and disposal activities would be similar to those described for Alternative 1A.	SMALL. Impacts to ecological resources from spent IER handling, transport, and disposal activities would be similar to those described for Alternative 1A.	SMALL. Impacts to ecological resources from spent IER handling, transport, and disposal activities would be similar to those described for Alternative 1A. Construction of the small, onsite spent IER storage facilities would occur within existing, operating NPP footprints and boundaries. These storage facilities would occupy very small areas in comparison to current NPP site footprints (i.e., about 0.04-0.07% of total NPP site areas, on average; see Section 4.2.4), and thus would affect only very small areas	SMALL. Impacts to ecological resources from spent IER handling, thermal processing (volume reduction), transport, and disposal activities would be similar to those described for Alternative 1A. Construction of a long-term spent IER storage facility would occur at an existing, operating waste disposal site. This storage facility would occupy a relatively small area in comparison to the waste disposal facility footprint (i.e., less than 1% of total waste disposal facility site areas see Section 4.2.5), and	SMALL. Impacts to ecological resources from spent IER handling, thermal processing (volume reduction), transport, and disposal activities would be similar to those described for Alternative 1A.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	**ALTERNATIVE 1B** DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	**ALTERNATIVE 2** DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	**ALTERNATIVE 3** LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]	**ALTERNATIVE 4A** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]	**ALTERNATIVE 4B** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]
ECOLOGICAL RESOURCES ***(Cont.)***	noise levels and any associated ecological impacts to a minimum.			of land. Impacts to ecological resources, if any, would be minimized through threatened and endangered (T&E) species surveys, consultation with the U.S. Fish and Wildlife Service (USFWS) and corresponding State agencies, and avoidance or mitigation, where possible. Impacts, if any, might be somewhat greater than for Alternatives 1A, 1B, 2, and 4B, in which no such construction would occur. No additional ecological impacts would be expected during operation of the long-term spent IER storage facilities at the NPPs.	thus would affect only a very small area of land. Impacts to ecological resources, if any, would be minimized through T&E species surveys, consultation with the USFWS and corresponding State agencies, and avoidance or mitigation, where possible. Impacts, if any, might be somewhat greater than for Alternatives 1A, 1B, 2, and 4B, in which no such construction would occur. No additional ecological impacts would be expected during operation of the long-term spent IER storage facility.	
HISTORIC AND CULTURAL RESOURCES	SMALL. The existing NPPs and mechanical mixing (blending) and disposal facilities would be operating within existing facility footprints. There would be minimal or no	SMALL. Impacts to historic and cultural resources from spent IER handling, thermal processing (blending), transport, and	SMALL. Impacts to historic and cultural resources from spent IER handling, transport, and disposal activities would be similar to	SMALL. Impacts to historic and cultural resources from spent IER handling, transport, and disposal activities would be similar to those described for Alternative 1A.	SMALL. Impacts to historic and cultural resources from spent IER handling, thermal processing (volume reduction), transport, and disposal activities would be similar	SMALL. Impacts to historic and cultural resources from spent IER handling, thermal processing (volume reduction), transport, and disposal activities

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	<u>ALTERNATIVE 1A</u> **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**<u>ALTERNATIVE 1B</u>** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**<u>ALTERNATIVE 2</u>** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**<u>ALTERNATIVE 3</u>** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**<u>ALTERNATIVE 4A</u>** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**<u>ALTERNATIVE 4B</u>** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
<u>HISTORIC AND CULTURAL RESOURCES</u> ***(Cont.)***	additional ground disturbance during spent IER handling and processing and none during spent IER transport. Therefore, no destruction of, or other adverse effects on, historic or cultural resources would be expected as a result of these activities.	disposal activities would be similar to those described for Alternative 1A.	those described for Alternative 1A.	SMALL to MODERATE. Construction of the small, onsite spent IER storage facilities would occur within existing NPP sites. Historic and cultural resources eligible for listing on the *National Register of Historic Places* (NRHP), if any, would be identified through cultural resource inventories and surveys and subsequently avoided, minimized, or mitigated according to requirements of the National Historic Preservation Act (NHPA) Section 106 regulations and through consultations with State Historic Preservation Officers (SHPOs) and Tribal Historic Preservation Officers (THPOs), as appropriate. However, due to the small sizes of these new storage facilities (see Section 4.2.4), impacts could likely be avoided. No additional impacts to	to those described for Alternative 1A. SMALL to MODERATE. Construction of a relatively small long-term spent IER storage facility would occur at an existing waste disposal site. Historic and cultural resources eligible for listing on the NRHP would be identified through cultural resource inventories and surveys and subsequently avoided, minimized, or mitigated according to requirements of the NHPA Section 106 regulations and through consultations with the SHPO and THPO, as appropriate. However, due to the small size of the new storage facility (see Section 4.2.5), impacts could likely be avoided. No additional impacts to historic and cultural resources would be expected during operation of the long-term spent IER	would be similar to those described for Alternative 1A.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	**POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE**[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL**[b]	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL**[b]	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL**[b]
HISTORIC AND CULTURAL RESOURCES ***(Cont.)***				historic and cultural resources would be expected during operation of the long-term spent IER storage facilities.	storage facility.	
NOISE *(NOTE: Noise impacts associated with the transport of spent IERs are addressed later in this table, under Transportation: Local and National Traffic.)*	SMALL. Noise resulting from spent IER handling, mechanical mixing (blending), and disposal would occur at existing, licensed facilities in compliance with applicable noise regulations, and noise mitigation measures would typically be employed where necessary.	SMALL. Impacts from noise generated by spent IER handling, thermal processing (blending), and disposal activities would be similar to those described for Alternative 1A.	SMALL. Impacts from noise generated by spent IER handling, and disposal activities would be similar to those described for Alternative 1A. This alternative involves no waste processing and associated noise impacts.	SMALL. Impacts from noise generated by spent IER handling, and disposal activities would be similar to those described for Alternative 1A. This alternative involves no waste processing and associated noise impacts. Construction of the small onsite waste storage facilities at the NPPs would result in temporary and intermittent construction noise impacts. In populated areas, construction activities may be scheduled to minimize potential noise impacts and avoid disturbing the public. Minimal or no additional noise impacts would be expected during operation of the long-term spent IER storage facilities.	SMALL. Impacts from noise generated by spent IER handling, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1A. Construction of a relatively small, long-term spent IER storage facility at the waste disposal site would result in temporary and intermittent construction noise impacts. If in a populated area, construction activities may be scheduled to minimize potential noise impacts and avoid disturbing the public. Minimal or no additional noise impacts would be expected during operation of the long-term spent IER storage facility.	SMALL. Impacts from noise generated by spent IER handling, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1A.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
PUBLIC AND OCCUPATIONAL HEALTH: ***Occupational Health – Radiological***	SMALL. Workers performing spent IER handling, transport, mechanical mixing (blending), and disposal activities operate within an environment subject to OSHA regulations in 29 CFR 1910, the U.S. Nuclear Regulatory Commission (NRC) Standards for Protection Against Radiation (10 CFR Part 20), Agreement State requirements (where applicable), radiological practices and procedures to achieve and maintain radiological exposure to levels that are as low as reasonably achievable (ALARA), and safety standard operating procedures (SOPs) developed for specific tasks. Worker radiological dose rates may increase minimally; however, illness rates would not be expected to increase from the above activities when	SMALL. Radiological impacts to workers performing spent IER handling, transport, thermal processing (blending), and disposal activities would be similar to those described for Alternative 1A.	SMALL. Radiological impacts to workers performing spent IER handling, transport, and disposal activities in this alternative could be somewhat less than those described for Alternatives 1A, 1B, 4A, and 4B because no radioactive waste processing (i.e., blending or volume reduction) step would be involved. These impacts could also be somewhat less than those for Alternatives 3 and 4A because no worker exposure during long-term storage of spent IERs would occur.	SMALL. Radiological impacts to workers performing spent IER handling, transport, and disposal activities, would be similar to those described for Alternative 1A. Although there could be less worker exposure in this alternative, as compared to that for Alternatives 1A, 1B, 4A, and 4B, because no radioactive waste processing would be involved, this could be offset to some degree by worker exposure during the long-term storage of spent IERs at the NPPs (although this exposure would still be minimal due to OSHA and other safety requirements). There would be no radiological impacts to workers resulting from construction of the long-term spent IER storage facilities at the NPPs because no radioactive materials would be	SMALL. Radiological impacts to workers performing spent IER handling, transport, thermal processing (volume reduction), long-term storage, and disposal activities could be somewhat higher than those described for Alternatives 1A, 1B, and 4B because this alternative involves the additional activity of long-term storage of spent IERs at the waste disposal site (although this exposure would still be minimal due to OSHA and other safety requirements). There would be no radiological impacts to workers resulting from construction of the long-term spent IER storage facility because no radioactive materials would be used during construction.	SMALL. Radiological impacts to workers performing spent IER handling, transport, thermal processing (volume reduction), and disposal activities, would be similar to those described for Alternative 1A..

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	**POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]**					
	<u>ALTERNATIVE 1A</u> **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**<u>ALTERNATIVE 1B</u>** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**<u>ALTERNATIVE 2</u>** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**<u>ALTERNATIVE 3</u>** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**<u>ALTERNATIVE 4A</u>** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**<u>ALTERNATIVE 4B</u>** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
<u>PUBLIC AND OCCUPATIONAL HEALTH</u>: ***Occupational Health – Radiological (Cont.)***	in adherence to the above stated requirements, practices, and procedures.			used during construction.		
<u>PUBLIC AND OCCUPATIONAL HEALTH</u>: ***Occupational Health – Non-radiological***	SMALL. Workers performing spent IER handling, transport, mechanical mixing (blending), and disposal activities operate within an environment subject to OSHA and other Federal regulations, as well as safety SOPs developed for specific tasks. As a result, worker injury and illness rates would not be expected to increase from these activities.	SMALL. Non-radiological impacts to workers performing spent IER handling, transport, thermal processing (blending), and disposal activities would be similar to those described for Alternative 1A.	SMALL. Non-radiological impacts to workers performing spent IER handling, transport, and disposal activities in this alternative could be somewhat less than those described for Alternatives 1A, 1B, 4A, and 4B because no waste processing (i.e., blending or volume reduction) step would be involved.	SMALL. Non-radiological impacts to workers performing spent IER handling, transport, and disposal activities, would be similar to those described for Alternative 1A. Workers involved in the construction of long-term waste storage facilities at the NPPs would be exposed to typical risks associated with construction activities. However, these activities would be subject to OSHA and other applicable safety requirements and SOPs. Non-radiological impacts to workers during maintenance and monitoring of the long-term	SMALL. Non-radiological impacts to workers performing spent IER handling, transport, thermal processing (volume reduction), long-term storage, and disposal activities would be similar to those described for Alternative 1A. Workers involved in the construction of the long-term waste storage facility at the waste disposal site would be exposed to typical risks associated with construction activities. However, these activities would be subject to OSHA and other applicable safety requirements and SOPs. Non-radiological impacts to workers during	SMALL. Non-radiological impacts to workers performing spent IER handling, transport, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1A.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
PUBLIC AND OCCUPATIONAL HEALTH: ***Occupational Health – Non-radiological (Cont.)***				spent IER storage facilities would be expected to be minimal.	maintenance and monitoring of the long-term spent IER storage facility would be expected to be minimal.	
PUBLIC AND OCCUPATIONAL HEALTH: ***Public Health – Radiological*** *(NOTE: Radiological impacts to public health from incident-free transportation and transportation accidents are described later in this table under Transportation.)*	SMALL. Minimal or no exposure of the public to radiological constituents would be expected to occur from the spent IER handling, mechanical mixing (blending), and disposal activities due to safety-related procedures and regulatory controls implemented during these operations and the physical separation of the public (due to access limitations and distance) from these operations. In addition, the blending and waste disposal facilities would maintain compliance with applicable Federal, State, and local regulations for the protection of air quality and water quality and for waste	SMALL. Radiological impacts to public health from spent IER handling, thermal processing (blending), and disposal activities would be similar to those described for Alternative 1A.	SMALL. Minimal or no exposure of the public to radiological constituents would be expected to occur from the spent IER handling and disposal activities due to safety-related procedures and regulatory controls implemented during these operations. This alternative involves no waste processing and associated public health impacts.	SMALL. Minimal or no exposure of the public to radiological constituents would be expected to occur from the spent IER handling and disposal activities due to safety-related procedures and regulatory controls implemented during these operations. This alternative involves no waste processing and associated public health impacts. There would be no radiological impacts to the public resulting from construction of the long-term spent IER storage facilities at the NPPs because no radioactive materials would be used during construction. Long-	SMALL. Impacts to public health from spent IER handling, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1A. There would be no radiological impacts to the public resulting from construction of the long-term spent IER storage facility at the waste disposal site because no radioactive materials would be used during construction. Long-term waste storage is not anticipated to result in public health impacts due to the implementation of maintenance and	SMALL. Impacts to public health from spent IER handling, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1A.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	**ALTERNATIVE 1B** DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	**ALTERNATIVE 2** DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	**ALTERNATIVE 3** LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]	**ALTERNATIVE 4A** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]	**ALTERNATIVE 4B** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]
PUBLIC AND OCCUPATIONAL HEALTH: ***Public Health – Radiological (Cont.)***	management, thus minimizing potential impacts to the public (see under Air Quality (Radiological), Waste Management, and Water Resources (Water Quality) in this table).			term storage of spent IERs is not anticipated to result in public health impacts due to the implementation of maintenance and monitoring programs.	monitoring programs.	
PUBLIC AND OCCUPATIONAL HEALTH: ***Public Health – Non-radiological*** *(NOTE: Non-radiological impacts to public health from transportation accidents are described later in this table under Transportation.)*	SMALL. Minimal or no exposure of the public to non-radiological constituents would be expected to occur from the spent IER handling, mechanical mixing (blending), and disposal activities due to safety-related procedures and regulatory controls implemented during these operations and the physical separation of the public (due to access limitations and distance) from these operations. In addition, the mechanical mixing (blending) facility would maintain compliance with applicable Federal, State, and local regulations for air quality, noise, and	SMALL. Non-radiological impacts to public health from spent IER handling, thermal processing (blending), and disposal activities would be similar to those described for Alternative 1A.	SMALL. Non-radiological impacts to public health from spent IER handling and disposal activities would be similar to those described for Alternative 1A. This alternative involves no waste processing and associated public health impacts.	SMALL. Non-radiological impacts to public health from waste handling and disposal activities would be similar to those described for Alternative 1A. This alternative involves no waste processing and associated public health impacts. Non-radiological impacts to public health from construction of the small onsite waste storage facilities at the NPPs are addressed in this table under Air Quality (Non-radiological), Noise, and Water Resources (Water Quality). Long-term storage of spent IERs at the NPPs is not anticipated	SMALL. Non-radiological impacts to public health from waste handling, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1A. Non-radiological impacts to public health from construction of the small onsite waste storage facilities at the NPPs are addressed in this table under Air Quality (Non-radiological), Noise, and Water Resources (Water Quality). Long-term storage of spent IERs at the waste disposal site is not anticipated to result in public health impacts due	SMALL. Non-radiological impacts to public health from spent IER handling, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1A.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	**POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE**[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL**[b]	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL**[b]	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL**[b]
PUBLIC AND OCCUPATIONAL HEALTH: ***Public Health – Non-radiological (Cont.)***	water quality protection and for waste management, thus minimizing potential impacts to the public (see under Air Quality (Non-radiological), Noise, Waste Management, and Water Resources (Water Quality) in this table). Criteria emissions (e.g., particulate matter) from disposal activities, with commensurate public health impacts, would be minimized through the implementation of BMPs (e.g., pollution controls on equipment, dust suppression techniques), and distance to public receptors.			to result in public health impacts due to the implementation of maintenance and monitoring programs.	to the implementation of maintenance and monitoring programs.	
SOIL	SMALL. No activities would take place during spent IER handling, transport, and mechanical mixing (blending) that would result in soil disturbance or contamination, other than	SMALL. Soil impacts as a result of spent IER handling, transport, thermal processing (blending), and disposal activities would be similar to	SMALL. Soil impacts as a result of spent IER handling, transport, and disposal activities would be similar to those described for	SMALL. Soil impacts as a result of spent IER handling, transport, and disposal activities under this alternative would be similar to those described for Alternative 1A. This alternative involves no	SMALL. Soil impacts as a result of spent IER handling, transport, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1A.	SMALL. Soil impacts as a result of spent IER handling, transport, thermal processing (volume reduction), and disposal activities would be similar to those described for

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	**ALTERNATIVE 1B** DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	**ALTERNATIVE 2** DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	**ALTERNATIVE 3** LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]	**ALTERNATIVE 4A** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]	**ALTERNATIVE 4B** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]
SOIL *(Cont.)*	minor accidental spills that would be immediately addressed in accordance with spill prevention, control, and counter-measures (SPCC) plans. Waste disposal activities would include application of BMPs (e.g., earth berms, dikes, sediment fences) to reduce soil erosion and implementation of SPCC plans for cleanup of accidental spills.	those described for Alternative 1A.	Alternative 1A. This alternative involves no waste processing and associated soil impacts, if any.	waste processing and associated soil impacts. Construction of the small, onsite spent IER storage facilities at the NPPs would involve soil disturbance. Application of BMPs (e.g., earth berms, dikes, sediment fences) would reduce soil erosion. Implementation of SPCC plans would reduce potential impacts from chemical spills or releases during both construction and operation of the storage facilities.	Construction of the long-term spent IER storage facility at the waste disposal site would involve soil disturbance. Application of BMPs (e.g., earth berms, dikes, sediment fences) would reduce soil erosion. Implementation of an SPCC Plan would reduce potential impacts from chemical spills or releases during both construction and operation of the storage facility.	Alternative 1A.
TRANSPORTATION: ***Local and National Traffic***[c]	SMALL. On the local level, there would be about 1 spent IER truck per operating hour and about 1 truck per every 2 operating hours on average, near the waste processing (blending) facility and waste disposal facility, respectively. These numbers of trucks would represent very small additions to local traffic	SMALL. Alternatives 1B and 1A differ only in the method of blending employed, and the numbers of annual truck trips to and from the waste processing and waste disposal facilities in these two alternatives would be the same.	SMALL. On the local level, there would be about 1 spent IER truck every 2 operating hours, on average, near the waste disposal facility. This would represent a very small addition to local traffic in the vicinity of a waste	SMALL. On the local level, in Years 1-20, there would be about 1 truck every 2.5 operating hours, on average, near the waste disposal facility. These numbers of trucks would represent very small additions to local traffic near a waste disposal site. On the national level, in Years 1-20, total annual	SMALL. On the local level, there would be about 1 truck per 8-hour operating day and 1 truck every 2 operating hours, on average, near the waste processing (volume reduction) facility and waste disposal facility, respectively. These numbers of trucks would represent very small additions to local traffic	SMALL. Impacts on local and national traffic would be similar to those described for Alternative 4A.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	**ALTERNATIVE 1B** DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	**ALTERNATIVE 2** DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	**ALTERNATIVE 3** LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]	**ALTERNATIVE 4A** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]	**ALTERNATIVE 4B** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]
TRANSPORTATION: ***Local and National Traffic (Cont.)***	near industrial and waste disposal sites. On the national level, total annual spent IER shipments (full and empty casks) would constitute approximately 0.0005% of total tractor-trailer truck freight weight on U.S. roads each year and, therefore, an even smaller (negligible) percentage of the total annual national vehicle traffic. Corresponding to the small local and national traffic impacts described above, there would be small impacts on associated traffic congestion, air quality, noise levels, and road surface wear. Non-radiological air emissions (e.g., from vehicle exhaust) from trucks transporting spent IERs and empty casks would be minimal due to the small scale and intermittent	Therefore, impacts on local and national traffic would be similar to those described for Alternative 1A.	disposal site. On the national level, total annual spent IER shipments (full and empty casks) would constitute approximately 0.0003% of total tractor-trailer truck freight weight on U.S. roads each year and, therefore, an even smaller (negligible) percentage of the total annual national vehicle traffic. Corresponding small local and national impacts on traffic congestion, air quality, noise levels, and road surface wear would be as described under Alternative 1A.	spent IER shipments (full and empty casks) would constitute approximately 0.0002% of total tractor-trailer truck freight weight on U.S. roads each year and, therefore, an even smaller (negligible) percentage of the total annual national vehicle traffic. Impacts on local and national traffic after Year 21 would be similar to those of Alternative 2, as both of these alternatives involve direct disposal of all Class A, B, and C spent IERs. Corresponding small local and national impacts on traffic congestion, air quality, noise levels, and road surface wear would be as described under Alternative 1A.	near industrial and waste disposal sites. On the national level, total annual spent IER shipments (full and empty casks) would constitute approximately 0.0003% of total tractor-trailer truck freight weight on U.S. roads each year and, therefore, an even smaller (negligible) percentage of the total annual national vehicle traffic. Corresponding small local and national impacts on traffic congestion, air quality, noise levels, and road surface wear would be as described under Alternative 1A.	

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
TRANSPORTATION: ***Local and National Traffic (Cont.)***	nature of these operations, which would be dispersed over wide geographic areas.					
TRANSPORTATION: ***Routine (Incident-free) - Radiological (Individuals and Populations)[c]*** *(NOTE: In actuality, all of the radiation doses and LCFs would be lower than estimated here because people would not be at the same locations for an entire year. Also, not all trucks carrying spent IERs would stop at the same rest and refueling stops.)*	SMALL. For individuals, the maximally exposed individual (MEI) dose from moving trucks carrying all spent IER shipments annually would be approximately 0.07% of the average annual U.S. background radiation dose, and the corresponding LCF would be negligible at 3 x 10^{-11}% of 2010 total estimated U.S. cancer fatalities. For an average resident near a truck stop, the dose from trucks carrying all spent IER shipments annually would be approximately 0.12% of the background dose, and the corresponding LCF would be 5 x 10-11% of 2010 estimated cancer fatalities. Radiation doses and LCFs to all other	SMALL. Radiological impacts of routine transportation on individuals and populations would be similar to those described for Alternative 1A.	SMALL. For individuals, the MEI dose from moving trucks carrying all spent IER shipments annually would be approximately 0.04% of the average annual U.S. background radiation dose, and the corresponding LCF would be negligible at 1 x 10^{-11}% of 2010 total estimated U.S. cancer fatalities. For an average resident near a truck stop, the dose from trucks carrying all spent IER shipments annually would be approximately	SMALL. For individuals, in Years 1-20, the MEI dose from moving trucks carrying all spent IER shipments annually would be approximately 0.03% of the average annual U.S. background radiation dose, and the corresponding LCF would be negligible at 1 x 10^{-11}% of 2010 total estimated U.S. cancer fatalities. For an average resident near a truck stop, the dose from trucks carrying all spent IER shipments annually would be approximately 0.050% of the background dose, and the corresponding LCF would be 2 x 10^{-11}% of 2010 estimated cancer fatalities. Radiation doses and LCFs to all other individual receptors would	SMALL. For individuals, the MEI dose from moving trucks carrying all spent IER shipments annually would be approximately 0.04% of the average annual U.S. background radiation dose, and the corresponding LCF would be negligible at 1 x 10^{-11}% of 2010 total estimated U.S. cancer fatalities. For an average resident near a truck stop, the dose from trucks carrying all spent IER shipments annually would be approximately 0.066% of the background dose, and the corresponding LCF would be 3 x 10^{-11}% of 2010 estimated cancer fatalities. Radiation doses and LCFs to all other individual receptors would be orders of magnitude	SMALL. Radiological impacts of routine transportation on individuals and populations would be similar to those described for Alternative 4A.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
TRANSPORTATION: ***Routine (Incident-free) - Radiological (Individuals and Populations) (Cont.)***	individual receptors would be orders of magnitude lower. For populations along the representative transportation routes, the maximum annual collective population dose and LCF from moving trucks, from all annual spent IER shipments, would be about 4 x 10^{-5}% of the U.S. average annual background radiation dose and 3 x 10^{-9}% of 2010 total estimated U.S. cancer fatalities, respectively. For residents near rural and suburban truck rest and refueling stops, the maximum annual collective population doses, from all annual spent IER shipments, would each be about 0.2% of the U.S. average annual background dose, for the time these populations are exposed; and the		0.063% of the background dose, and the corresponding LCF would be 2 x 10^{-11}% of 2010 estimated cancer fatalities. Radiation doses and LCFs to all other individual receptors would be orders of magnitude lower. For populations along the representative transportation routes, the maximum annual collective population dose and LCF from moving trucks, from all annual spent IER shipments, would be about 9 x 10^{-5}% of the U.S. average annual background radiation dose and 2 x 10^{-9}% of 2010 total estimated U.S.	be orders of magnitude lower. For populations along the representative transportation routes, in Years 1-20, the maximum annual collective population dose and LCF from moving trucks, from all annual spent IER shipments, would be about 7 x 10^{-5}% of the U.S. average annual background radiation dose and 1 x 10^{-9}% of 2010 total estimated U.S. cancer fatalities, respectively. For residents near rural and suburban truck rest and refueling stops, in Years 1-20, the maximum annual collective population doses, from all annual spent IER shipments, would each be about 0.1% of the U.S. average annual background dose, for the time these populations are exposed; and the	lower. For populations along the representative transportation routes, the maximum annual collective population dose and LCF from moving trucks, from all annual spent IER shipments, would be about 7 x 10^{-5}% of the U.S. average annual background radiation dose and 4 x 10^{-10}% of 2010 total estimated U.S. cancer fatalities, respectively. For residents near rural and suburban truck rest and refueling stops, the maximum annual collective population doses, from all annual spent IER shipments, would each be about 0.1% of the U.S. average annual background dose, for the time these populations are exposed; and the maximum LCFs as percentages of 2010 total	

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
TRANSPORTATION: ***Routine (Incident-free) - Radiological (Individuals and Populations) (Cont.)***	maximum LCFs as percentages of 2010 total estimated U.S. cancer fatalities would be negligible at about 2 x 10^{-9}% and 4 x 10^{-8}%, respectively.		cancer fatalities, respectively. For residents near rural and suburban truck rest and refueling stops, the maximum annual collective population doses, from all annual spent IER shipments, would each be about 0.1% of the U.S. average annual background dose, for the time these populations are exposed; and the maximum LCFs as percentages of 2010 total estimated U.S. cancer fatalities would be negligible at about 8 x 10^{-10}% and 2 x 10^{-8}%, respectively.	maximum LCFs as percentages of 2010 total estimated U.S. cancer fatalities would be negligible at about 7 x 10^{-10}% and 2 x 10^{-8}%, respectively. Radiological impacts of routine transportation on individuals and populations after Year 21 would be similar to those described for Alternative 2.	estimated U.S. cancer fatalities would be negligible at about 9 x 10^{-10}% and 2 x 10^{-8}%, respectively.	
TRANSPORTATION: ***Accidents – Non-radiological and Radiological[c]***	SMALL. Regarding non-radiological impacts of transportation accidents, in the most conservative case evaluated, there	SMALL. Non-radiological and radiological impacts from transportation accidents would be	SMALL. Regarding non-radiological impacts of transportation accidents, in the	SMALL. Regarding non-radiological impacts of transportation accidents, in Years 1-20, in the most conservative case	SMALL. Regarding non-radiological impacts of transportation accidents, in the most conservative case evaluated, there would be	SMALL. Non-radiological and radiological impacts from transportation accidents would be

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	**POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]**					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
TRANSPORTATION: ***Accidents – Non-radiological and Radiological (Cont.)***	would be about 2.6 accidents per year involving trucks carrying spent IERs or empty casks, which is 0.0007% of the 2009 U.S. annual tractor-trailer truck accident rate. From these accidents, there would be about 0.02 fatality per year, which is equivalent to 1 fatal accident every 50 years and represents 0.004% of 2009 U.S. tractor-trailer truck fatalities. Regarding radiological impacts of transportation accidents in which no radioactive materials are released, in the most conservative case evaluated, the collective population dose as a percentage of U.S. average annual background dose would be 0.01%, and the corresponding LCF as a percentage of estimated	similar to those described for Alternative 1A.	most conservative case evaluated, there would be about 2 accidents per year involving trucks carrying spent IERs or empty casks, which is 0.0004% of the 2009 U.S. annual tractor-trailer truck accident rate. From these accidents, there would be about 0.01 fatality per year, which is equivalent to 1 fatal accident every 100 years and represents 0.002% of 2009 U.S. tractor-trailer truck fatalities. Regarding radiological impacts of transportation accidents in which no radioactive materials are released, in the	evaluated, there would be about 1.3 accidents per year involving trucks carrying spent IERs or empty casks, which is 0.0003% of the 2009 U.S. annual tractor-trailer truck accident rate. From these accidents, there would be about 0.01 fatality per year, which is equivalent to 1 fatal accident every 100 years and represents 0.002% of 2009 U.S. tractor-trailer truck fatalities. Regarding radiological impacts of transportation accidents in which no radioactive materials are released, in Years 1-20, in the most conservative case evaluated, the collective population dose as a percentage of U.S. average annual background dose would be 0.004%, and the corresponding LCF as a percentage of estimated	about 1 accident per year involving trucks carrying spent IERs or empty casks, which is 0.0001% of the 2009 U.S. annual tractor-trailer truck accident rate. From these accidents, there would be about 0.01 fatalities per year, which is equivalent to 1 fatal accident every 100 years and represents 0.002% of 2009 U.S. tractor-trailer truck fatalities. Regarding radiological impacts of transportation accidents in which no radioactive materials are released, in the most conservative case evaluated, the collective population dose as a percentage of U.S. average annual background dose would be 0.005%, and the corresponding LCF as a percentage of estimated annual traffic fatalities involving spent IER	similar to those described for Alternative 4A.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	**POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE**[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL**[b]	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL**[b]	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL**[b]
TRANSPORTATION: ***Accidents – Non-radiological and Radiological (Cont.)***	annual traffic fatalities involving spent IER shipments and of 2010 estimated U.S. cancer fatalities would be 0.136% and 2.5 x 10^{-9}%, respectively. For the nearest member of the public, the MEI, the dose and LCF are 0.013% of background and 2.3 x 10^{-8}% of 2010 total estimated U.S. cancer fatalities, respectively. Regarding radiological impacts of transportation accidents in which radioactive materials could be released from Type A and Type B casks, accident consequences were calculated separately for accidents involving spent IERs from BWRs and PWRs and for a single accident scenario for each cask type (i.e., not for each of the six alternatives). For the Type A cask accident scenario, the MEI dose		most conservative case evaluated, the collective population dose as a percentage of U.S. average annual background dose would be 0.005%, and the corresponding LCF as a percentage of estimated annual traffic fatalities involving spent IER shipments and of 2010 estimated U.S. cancer fatalities would be 0.099% and 7.7 x 10^{-9}%, respectively. The potential radiological impact to the MEI would be the same as described under Alternative 1A. Regarding radiological impacts of transportation accidents in which radioactive	annual traffic fatalities involving spent IER shipments and of 2010 estimated U.S. cancer fatalities would be 0.078% and 1.2 x 10^{-9}%, respectively. The potential radiological impact to the MEI would be the same as described under Alternative 1A. Regarding radiological impacts of transportation accidents in which radioactive materials could be released from Type A and Type B casks, see discussion under Alternative 1A. Non-radiological and radiological impacts from transportation accidents after Year 21 would be similar to those described for Alternative 2.	shipments and of 2010 estimated U.S. cancer fatalities would be 0.078% and 1.2 x 10^{-9}%, respectively. The potential radiological impact to the MEI would be the same as described under Alternative 1A. Regarding radiological impacts of transportation accidents in which radioactive materials could be released from Type A and Type B casks, see discussion under Alternative 1A.	

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
TRANSPORTATION: ***Accidents – Non-radiological and Radiological*** **(Cont.)**	and LCF as percentages of U.S. average annual background and 2010 U.S. total estimated cancer fatalities would be 31% and 1 x 10^{-8}%, respectively, for either reactor type. For the Type B cask accident scenario, at most (for BWRs), the MEI dose and LCF as percentages of background and 2010 estimated cancer fatalities would be 17% and 6 x 10^{-9}%, respectively; and the corresponding collective dose and LCF percentages would be 0.22% and 2 x 10^{-7}%, respectively.		materials could be released from Type A and Type B casks, see discussion under Alternative 1A.			
WASTE MANAGEMENT	SMALL. Spent IER handling, transport, mechanical mixing (blending), and disposal activities would not result in substantial generation of incidental radioactive, hazardous, mixed, or non-hazardous solid waste or liquid effluent, based on	SMALL. Waste management impacts resulting from spent IER handling, transport, and disposal activities would be similar to those described for Alternative 1A.	SMALL. Waste management impacts resulting from spent IER handling, transport, and disposal activities would be similar to those described for Alternative 1A. No	SMALL. Waste management impacts resulting from spent IER handling, transport, and disposal activities would be similar to those described for Alternative 1A. No solid wastes or liquid effluents incidental to spent IER processing would be	SMALL. Waste management impacts resulting from spent IER handling, transport, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1B as these alternatives use similar	SMALL. Waste management impacts resulting from waste handling, transport, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1B as these

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	**POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]**					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
WASTE MANAGEMENT *(Cont.)*	the nature of these activities. Thus, there would be minimal resulting impacts on safety, waste disposal capacity, or other resources. Liquid effluents (including stormwater) would be managed in accordance with Federal and State regulations, including discharging within permitted limits (e.g., under NPDES requirements).	Small quantities of LLRW and hazardous waste would be generated as a result of the process, which would be managed in accordance with Federal and State regulations. Thus, there would be minimal resulting impacts on safety, waste disposal capacity, or other resources. Liquid effluents (including stormwater) would be managed in accordance with Federal and State regulations, including discharging within permitted limits (e.g., under NPDES requirements).	solid wastes or liquid effluents incidental to spent IER processing would be generated under this alternative.	generated under this alternative. Construction of the small onsite spent IER storage facilities at the NPPs could generate small quantities of hazardous and non-hazardous solid wastes, which would be managed in accordance with applicable Federal, State, and local requirements to avoid or minimize environmental impacts. Stormwater would be managed in accordance with NPDES requirements. Long-term spent IER storage at the NPPs would result in minimal generation, if any, of radioactive, hazardous, mixed, or non-hazardous solid waste, or liquid effluent. Liquid effluent would be managed in accordance with applicable regulations, including discharging within	thermal processing technologies, and all other component activities of the two alternatives would be essentially the same. Construction of a long-term spent IER storage facility at the waste disposal site could generate small quantities of hazardous and non-hazardous solid wastes, which would be managed in accordance with applicable Federal, State, and local requirements to avoid or minimize environmental impacts. Stormwater would be managed in accordance with NPDES requirements. Long-term spent IER storage would result in minimal generation, if any, of radioactive, hazardous, mixed, or non-hazardous solid waste, or liquid effluent. Liquid effluent would be managed in accordance with applicable	alternatives use similar thermal processing technologies, and all other component activities of the two alternatives would be essentially the same.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]					
	ALTERNATIVE 1A DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	**ALTERNATIVE 1B** DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	**ALTERNATIVE 2** DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	**ALTERNATIVE 3** LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]	**ALTERNATIVE 4A** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]	**ALTERNATIVE 4B** VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]
WASTE MANAGEMENT *(Cont.)*				permitted limits (e.g., under NPDES requirements).	regulations, including discharging within permitted limits (e.g., under NPDES requirements).	
WATER RESOURCES: *Water Quality*	SMALL. Little or no effluent discharges are anticipated from spent IER handling, transport, and disposal activities. Stormwater runoff would be managed in accordance with permit limits. Only permitted discharges of effluents would be allowed at the mechanical mixing (blending) facility. Discharges would be monitored in accordance Federal and State (e.g., NPDES) requirements that are protective of human health and the environment, thereby limiting any impacts to surface water and groundwater. Accidental spills would be immediately addressed in accordance with SPCC	SMALL. Water quality impacts resulting from spent IER handling, thermal processing (blending), transport, and disposal activities would be similar to those described for Alternative 1A.	SMALL. Water quality impacts resulting from spent IER handling, transport, and disposal activities would be similar to those described for Alternative 1A. No liquid effluents incidental to waste processing (i.e., blending or volume reduction) would be generated under this alternative.	SMALL. Water quality impacts resulting from spent IER handling, transport, and disposal activities would be similar to those described for Alternative 1A. No liquid effluents incidental to waste processing (i.e., blending or volume reduction) would be generated under this alternative. Effects of sediment discharge on water quality during construction of the small onsite spent IER storage facilities at the NPPs would be minimized through application of BMPs (e.g., earth berms, dikes, sediment fences). Accidental spills would be immediately addressed in accordance with SPCC plans. Little or no liquid	SMALL. Water quality impacts resulting from spent IER handling, transport, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1A. Effects of sediment discharge on water quality during construction of the relatively small long-term storage facility at the waste disposal site would be minimized through application of BMPs (e.g., earth berms, dikes, sediment fences). Accidental spills would be immediately addressed in accordance with an SPCC Plan. Little or no liquid effluent discharge is anticipated from long-term spent IER storage.	SMALL. Water quality impacts resulting from spent IER handling, transport, thermal processing (volume reduction), and disposal activities would be similar to those described for Alternative 1A.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	**POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE**[a]					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL**[b]	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL**[b]	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL**[b]
WATER RESOURCES: ***Water Quality (Cont.)***	plans.			effluent discharge is anticipated from long-term spent IER storage.		
WATER RESOURCES: ***Water Supply***	SMALL. There would be minimal water use associated with spent IER handling and transport. Small quantities of water would be used at the mechanical mixing (blending) facility and for dust suppression and other activities (e.g., equipment washing) at the waste disposal facility associated with the disposal of the relatively small quantities of spent IERs. Quantities of water used would result in minimal impacts to water supply.	SMALL. Water use impacts associated with spent IER handling, transport, and disposal would be similar to those described for Alternative 1A. Anticipated water use at the thermal processing (blending) facility would be low. Quantities of water used would result in minimal impacts to water supply.	SMALL. Water use impacts associated with spent IER handling, transport, and disposal would be similar to those described for Alternative 1A. There would be no water use associated with spent IER processing (i.e., blending or volume reduction) in this alternative.	SMALL. Water use impacts associated with spent IER handling, transport, and disposal would be similar to those described for Alternative 1A. There would be no water use associated with spent IER processing (i.e., blending or volume reduction) in this alternative. Construction of the small onsite spent IER storage facilities at the NPPs would require water for dust suppression and other construction activities (e.g., equipment washing), but the small quantities of water needed for these purposes would not be expected to result in impacts to water supply. There would be minimal water use associated with the long-term storage of	SMALL. Water use impacts associated with spent IER handling, thermal processing (volume reduction), transport, and disposal would be similar to those described for Alternative 1B as these alternatives employ similar thermal processing technologies, and all other component activities of the two alternatives would be essentially the same. Construction of the relatively small, long-term spent IER storage facility at the waste disposal site would require water for dust suppression and other construction activities (e.g., equipment washing), but the small quantities of water needed for these purposes would not be expected to result in	SMALL. Water use impacts associated with spent IER handling, thermal processing (volume reduction), transport, and disposal would be similar to those described for Alternative 1B as these alternatives employ similar thermal processing technologies, and all other component activities of the two alternatives would be essentially the same.

Table 5 Comparison of Potential Environmental Impacts of the Six Alternatives for Handling LLRW Spent Ion Exchange Resins (Cont.)

RESOURCE OR IMPACT AREA	**POTENTIAL ENVIRONMENTAL IMPACTS BY ALTERNATIVE[a]**					
	ALTERNATIVE 1A **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)**	**ALTERNATIVE 1B** **DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)**	**ALTERNATIVE 2** **DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW**	**ALTERNATIVE 3** **LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL[b]**	**ALTERNATIVE 4A** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL[b]**	**ALTERNATIVE 4B** **VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL[b]**
WATER RESOURCES: ***Water Supply (Cont.)***				spent IERs.	impacts to water supply. There would be minimal water use associated with the long-term storage of spent IERs.	

[a] Note that the six alternatives are assumed to be implemented at existing NPPs, waste processing facilities, and waste disposal facilities, and within the existing site boundaries and licensed envelopes of operation at those facilities.

[b] Alternative 3 includes immediate disposal of Class A LLRW spent IERs.

[c] See Appendix A for the basis of the quantitative results reported here.

5.2 Summary and Discussion of Comparative Environmental Evaluation

As shown in Table 5, the potential environmental impacts of all six alternatives in all resource and impact areas evaluated would be SMALL, with the exception of potential impacts on historic and cultural resources from construction of long-term spent IER storage facilities in Alternatives 3 and 4A, which could be SMALL to MODERATE. Note also that although implementation of Alternative 3 would require construction (expansion) of long-term spent IER storage areas at 65 NPP locations, these storage facilities would have small footprints, within existing NPP operational areas and under current license conditions, and at widely dispersed geographic locations; thus the impacts of these construction activities would not be cumulative in relation to each other. Furthermore, for reasons discussed earlier, conservative, often bounding assumptions were used in this comparative environmental evaluation of generic, non-location-specific alternatives in several cases, such that the actual impacts of the alternatives, if implemented, would be even smaller.

As summarized below, there are several reasons why the potential environmental impacts of all six alternatives would be mostly SMALL.

5.2.1 Air Quality

Nearly all of the radiological and non-radiological air emissions would come from the blending (mechanical mixing, thermal processing) and volume reduction facilities in Alternatives 1A, 1B, 4A, and 4B. Note that among Alternatives 1A, 1B, 4A, and 4B, air emissions from the ambient temperature mechanical mixing (blending) process in Alternative 1A would have the potential to be less than those from Alternative 1B (blending using thermal processing) and Alternatives 4A and 4B (volume reduction by thermal processing), which would involve treatment of spent IERs at elevated temperatures (800˚C) with resulting increased volatilization of constituents. However, emission controls (e.g., off-gas filtration equipment in the case of the thermal processing options) would be employed at these facilities as necessary to maintain compliance with applicable air quality regulations and keep emissions within regulatory limits under NESHAPs and NAAQS. Non-radiological air emissions from equipment usage and fugitive dust generation during spent IER handling and disposal, and during construction of relatively small, long-term spent IER storage facilities in Alternatives 3 and 4A, would be temporary and intermittent in nature and also subject to air quality regulations; and would be minimized and controlled using emissions controls, best management practices (BMPs), and other mitigation measures as necessary. Non-radiological air quality impacts associated with the transport of spent IERs are addressed below under Transportation—Local and National Traffic.

5.2.2 Ecological Resources

The existing NPPs and spent IER processing and disposal facilities would be operating within existing facility footprints. There would be minimal or no additional ground disturbance or other activities during spent IER handling and processing activities, and none during spent IER transport. Therefore, any impacts on wildlife and plants from these operations would be minimal. Any air emissions and wastewater discharges would be within regulatory limits and noise mitigation measures would keep noise levels and any associated ecological impacts to a minimum. Potential impacts from construction of long-term spent IER storage facilities in Alternatives 3 and 4A would be SMALL due to the very small sizes of these facilities; and would be avoided, minimized, or mitigated where possible, based on threatened and endangered species surveys and consultations with the USFWS and corresponding State agencies. No additional ecological impacts would be expected during operation of the long-term spent IER storage facilities.

5.2.3 Historic and Cultural Resources

The existing NPPs and waste processing and disposal facilities would be operating within existing facility footprints. There would be minimal or no additional ground disturbance during spent IER handling, processing, and disposal, and none during spent IER transport. Therefore, no destruction of, or other adverse effects on, historic or cultural resources would be expected as a result of these activities. Construction of long-term spent IER storage facilities in Alternatives 3 and 4A could possibly encounter and destroy, or otherwise adversely affect, resources determined eligible for listing in the NRHP (i.e., historic properties). However, the footprints of these storage facilities would be relatively small (see Sections 4.2.4 and 4.2.5), and conduct of cultural resource inventories and surveys, consultation with SHPOs and THPOs, and implementation of appropriate impact avoidance, minimization, or mitigation measures would keep the impacts to such resources at SMALL to MODERATE levels. No additional impacts to historic and cultural resources would be expected during operation of the long-term spent IER storage facilities.

5.2.4 Noise

Noise resulting from spent IER handling, processing, storage, and disposal would occur at existing, licensed facilities in compliance with applicable noise regulations and with noise mitigation measures typically employed as necessary. Noise impacts during construction of long-term spent IER storage facilities in Alternatives 3 and 4A would be temporary and intermittent in nature, and could be minimized in populated areas, if necessary, through suitable scheduling of construction activities and other measures. Minimal or no additional noise impacts would be expected during operation of the long-term spent IER storage facilities. Noise impacts associated with the transport of spent IERs are addressed below under Transportation—Local and National Traffic.

5.2.5 Public and Occupational Health

Worker activities for handling, processing, storage, and disposal of spent IERs must comply with NRC, Agreement State, OSHA, as low as reasonably achievable (ALARA), and other worker protection requirements and SOPs, as applicable, thus limiting any radiological and non-radiological occupational exposures to acceptable levels. The nature of facility operations, facility access limitations, applicable air quality, noise, water quality, and waste management regulatory requirements (e.g., air quality standards under NESHAPs and NAAQS, water quality requirements under NPDES), and emissions control and mitigation measures at the NPPs and waste processing and disposal facilities, and implementation of maintenance and monitoring programs at long-term spent IER storage facilities would result in minimal or no exposure of members of the public to radiological and non-radiological constituents.

5.2.6 Soil

Except for construction of long-term spent IER storage facilities at the NPPs in Alternative 3 and at the waste disposal site in Alternative 4A, essentially no activities would take place during spent IER handling and processing at the existing facilities, and during spent IER transport, that would result in soil disturbance or contamination, other than accidental spills, which would be immediately addressed in accordance with spill prevention, control, and countermeasures (SPCC) plans. Construction of long-term spent IER storage facilities at the NPPs and the waste disposal site in Alternatives 3 and 4A, respectively, and waste disposal activities, would involve application of BMPs (e.g., earth berms, dikes, sediment fences) to reduce soil erosion and implementation of SPCC plans for cleanup of accidental spills.

5.2.7 Transportation

As discussed below, for the three categories of potential transportation impacts assessed in this evaluation, the quantitatively estimated, potential non-radiological and radiological impacts to members of the public from the shipment of spent IERs and empty casks would be small to negligible in magnitude.

5.2.7.1 Local and National Traffic Impacts

On a local level, the numbers of trucks transporting spent IERs or empty casks on local roads near the waste processing or disposal facilities were estimated to range from about one truck per 8-hour operating day near the spent IER processing (volume reduction) facilities in Alternatives 4A and 4B, to about one truck per operating hour near the spent IER processing (blending) facilities in Alternatives 1A and 1B. This range in the numbers of trucks traveling on local roads represents very small additions to local traffic in the vicinities of industrial sites. On a national level, total annual spent IER freight shipments (full and empty casks) would constitute approximately 0.0002 to 0.0005 percent (depending on the alternative) of the total annual U.S. freight weight carried by tractor-trailer trucks. These percentages would be even smaller (negligible) as compared to total annual national vehicle traffic (tractor-trailer trucks plus all other vehicles). Corresponding to these small local and national traffic impacts, there would be small impacts on associated traffic congestion, air quality, noise levels, and road surface wear.

5.2.7.2 Radiological Impacts of Routine Transportation

For individuals, the highest estimated doses and corresponding LCFs would be to the MEI and to residents near truck stops, although these would all be low. However, the radiological impacts of the alternatives would be similar to each other. The MEI dose from moving trucks carrying all spent IER shipments annually would range from approximately 0.03 to 0.07 percent of the average annual U.S. background radiation dose; and the corresponding LCFs would be negligible, ranging from about 1×10^{-11} to 3×10^{-11} percent of 2010 total estimated U.S. cancer fatalities. For an average resident near a truck stop, the dose from trucks carrying all spent IER shipments annually would range from approximately 0.050 to 0.12 percent of the background dose, and the corresponding LCFs would range from 2 x 10^{-11} to 5 x 10^{-11} percent of 2010 estimated cancer fatalities. Radiation doses and LCFs to all other individual receptors would be orders of magnitude lower.

For populations along the representative transportation routes and near truck rest and refueling stops, the maximum annual collective population doses and LCFs from moving and stationary trucks, respectively, from all annual spent IER shipments for each of the six alternatives, would also be similar. Collective population doses from moving trucks would range from about 6 x 10^{-6} to 7 x 10^{-5} percent of the U.S. average annual background radiation dose; and corresponding LCFs would be negligible, ranging from about 1 x 10^{-10} to 3 x 10^{-9} percent of 2010 total estimated U.S. cancer fatalities, respectively. For trucks at rural and suburban rest and refueling stops, collective population doses from stationary trucks would range from about 0.03 to 0.2 percent of background; and corresponding LCFs would be negligible, ranging from about 1 x 10^{-8} to 4 x 10^{-8} percent of 2010 estimated cancer fatalities, respectively. Any differences between the collective doses to residents near rural and suburban truck stops depend only on the difference in population (with the populations near suburban trucks stops typically being higher). The radiation source and its strength are the same in both cases.

Note that in actual practice, impacts to both individuals and populations would be lower than estimated because not all residents would be at the same locations for an entire year and not all trucks carrying spent IERs would stop at the same rest and refueling stops.

5.2.7.3 Non-radiological and Radiological Impacts of Transportation Accidents

Regarding non-radiological impacts of transportation accidents, in the most conservative case evaluated in the transportation analysis, there would be about 2.6 accidents per year involving trucks carrying spent IERs or empty casks, which is 0.0007 percent of the 2009 U.S. annual tractor-trailer truck accident rate. From these accidents, there would be about 0.02 traffic fatality per year, which is equivalent to 1 fatal accident every 50 years and represents 0.004 percent of 2009 U.S. tractor-trailer truck accident fatalities. There is little variation between these results for the various alternatives and representative transportation routes evaluated.

Regarding radiological impacts of transportation accidents in which no radioactive materials are released, for the most conservative cases evaluated in the analysis, the collective population dose as a percentage of U.S. average annual background dose would be 0.01 percent, and the corresponding collective LCF as a percentage of estimated annual traffic fatalities involving spent IER shipments and of 2010 estimated U.S. cancer fatalities would be 0.136 percent and 7.7 x 10^{-9} percent, respectively. Again, there is little variation between these results for the various alternatives and representative transportation routes.

Regarding radiological impacts of transportation accidents in which radioactive materials could be released from Type A and Type B casks: (a) For the Type A cask accident scenario, the MEI dose and LCF as percentages of U.S. average annual background and 2010 U.S. total estimated cancer fatalities would be 31 percent and 1 x 10^{-8} percent, respectively, for BWRs and PWRs; (b) For the Type B cask accident scenario, at most (for BWRs), the MEI dose and LCF as percentages of background and 2010 estimated cancer fatalities would be 17 percent and 6 x 10^{-9} percent, respectively; and the corresponding collective dose and LCF percentages would be 0.22 percent and 2 x 10^{-7} percent, respectively.

5.2.8 Waste Management

Spent IER handling, transport, processing, and disposal, and construction of relatively small long-term spent IER storage facilities, would not result in substantial generation of radioactive, hazardous, mixed, or non-hazardous solid waste that would adversely affect safety, waste disposal capacity, or other resources. Liquid effluents (including stormwater) from facility operations and construction activities would be managed in accordance with applicable Federal and State regulations, including discharging within permitted limits (e.g., NPDES requirements).

5.2.9 Water Resources

With regard to water quality, only permitted liquid effluent discharges, within regulatory limits, would be allowed at all facilities, as applicable. Sediment discharges during construction of the relatively small long-term spent IER storage facilities in Alternatives 3 and 4A would be controlled through implementation of BMPs (e.g., earth berms, dikes, sediment fences). Accidental spills would be immediately addressed in accordance with SPCC plans. With regard to potential impacts on water supply, the small quantities of water that would be used at the spent IER processing facilities, and for dust suppression and other activities (e.g., equipment washing) at the waste disposal facilities and during construction of the relatively small long-term spent IER storage facilities in Alternatives 3 and 4A, would be expected to result in minimal impacts to water supply. There would be minimal water use associated with spent IER handling, transport, and long-term storage.

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APPENDIX A
TRANSPORTATION ANALYSIS: METHODOLOGY, ASSUMPTIONS, AND POTENTIAL IMPACTS

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A.1 Introduction

A.1.1 Overview

This appendix presents a detailed technical analysis of potential transportation impacts of the six alternatives identified by the U.S. Nuclear Regulatory Commission (NRC) staff for handling low-level radioactive waste (LLRW) spent ion exchange resins (IERs) from commercial nuclear power plants (NPPs). Sections 3.1 and 4 of the main report present descriptions of the six alternatives. This analysis was prepared with assistance from the Risk and Reliability Analysis Department and Environmental Safety and Testing Department of Sandia National Laboratories (SNL), Albuquerque, New Mexico.

For reasons discussed in Section 3.1, the six alternatives evaluated in this report are generic and not location-specific. The transportation analysis is based on conservative, often bounding assumptions that are consistent with the alternatives. Note also that the transportation impact evaluation used quantitative information such as estimated numbers of shipments of full and empty spent IER shipping casks, quantities of waste transported in shipments, and trip lengths and population densities based on representative transportation routes. Results are correspondingly expressed quantitatively, although they are limited by the generic, non-location-specific nature of the six alternatives and, therefore, are also assessed qualitatively in this appendix and in the main report.

Additionally, this analysis focuses entirely on the potential impacts of transportation of the spent IERs, primarily because the bulk of potential transportation impacts of the six alternatives would result from the shipment of these wastes. It is recognized that there would also be impacts resulting from transportation of operational workforces, raw materials, supplies, and incidental process wastes to and from the waste processing and disposal facilities. Transportation impacts related to the operations of the NPPs are not addressed because these impacts have already been assessed by the NRC in the environmental impact statements (EIS's) prepared in association with the licensing of these facilities.

As discussed in Section 4.1.2.1, when transported on public roadways, the spent IERs are shipped in shielded shipping containers, or casks, on large, legal weight or overweight trucks (usually 18-wheel, semi-detached flatbed trailer trucks). In the six alternatives considered in this evaluation, spent IER truck shipments of full and returned empty shipping casks may occur between NPPs and centralized waste processing facilities (for spent IER blending or volume reduction), between NPPs and LLRW disposal facilities, and between waste processing facilities and LLRW disposal facilities. The potential effects of routine transportation[1] of untreated and treated (processed) spent IERs and empty casks in the various alternatives on traffic volumes and patterns (e.g., traffic congestion) nationally and in areas local to the waste processing and

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[1] Routine transportation takes place without incident. A transportation incident is any event that interferes with transportation between origin and destination. A transportation accident is an event that results in death, injury, or enough damage to an involved vehicle that the vehicle cannot move under its own power. All accidents are incidents.

waste disposal facilities are considered in the analysis. Routine transportation of radioactive materials could also affect air quality, noise, and road surface wear.

In addition, transporting radioactive materials under any conditions could pose inherent risks and impacts to members of the public due to possible radiation exposure during routine transportation or because of transportation accidents. Facilities and transporters that handle radioactive materials must comply with regulatory requirements and have standard operating procedures (SOPs) in place to minimize these risks and protect worker and public health and safety. Note that exposures of "radiation workers" (e.g., truck crews, package handlers, inspectors, and emergency responders) are not considered in this analysis because these workers are specially trained in, and knowledgeable of, necessary hazardous materials and radiation safety requirements and procedures, and are monitored and have radiation exposure limits stipulated by NRC regulation in 10 CFR 20.1201.

Three categories of transportation impacts listed below are assessed in this evaluation. These categories capture the range of reasonable potential impacts to the public from the transportation of spent IERs (full and empty casks).

- Impacts of spent IER shipments on local traffic near centralized waste processing facilities and LLRW disposal facilities, and on total traffic in the U.S. Vehicle traffic on public roadways, including large trucks that carry spent IERs and empty shipping containers, affects air quality (e.g., due to vehicle exhaust emissions), noise levels, traffic accident likelihood, and roadway congestion. The potential impacts on local traffic near centralized spent IER processing facilities (for blending or volume reduction) and LLRW disposal facilities are analyzed. The analysis assumes that spent IER processing facilities would most likely be located in industrial areas with already existing large truck traffic and other vehicular traffic associated with the operations of the various industrial and commercial facilities in these areas. LLRW disposal facilities are typically located far from populated areas. The potential impact that the trucks would have on national traffic is also analyzed. In both cases (local and national), the associated transportation impacts would be like those from any other large tractor-trailer trucks carrying cargo on public roadways.

- Radiological impacts to members of the public from routine, incident-free transport of spent IERs. Radiation doses[2] to members of the public (individuals and populations) during routine spent IER shipments (full containers) are estimated using the RADTRAN 6 computer code (Neuhauser et al., 2000; Weiner et al., 2009). Such radiation doses could result from external radiation emanating from the shipping casks. RADTRAN 6 is the nationally accepted, standard computer program for calculating the risks of transporting radioactive materials.

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[2] Radiation dose, or simply dose, is a measure of the biological damage to an individual from ionizing radiation. Millisieverts (mSv) are the unit of measure of the effect ionizing radiation has on people. As a point of reference, the average annual background *dose* from natural sources of radiation received by a person in the U.S. is about 3.6 mSv (Shleien et al., 1998).

- Non-radiological and radiological impacts to members of the public from transportation accidents involving spent IER shipments. Accidents during transport of spent IERs (full casks) could have both non-radiological and radiological impacts on members of the public. Non-radiological impacts of transportation accidents are assessed in terms of the estimated numbers of traffic accident and traffic accident fatalities from implementation of each alternative. RADTRAN 6 is used to estimate the potential radiological impacts for cases in which radioactive materials (i.e., spent IERs) are not released and are released to the environmental as a result of transportation accidents.

A.1.2 Key General Assumptions Used in This Transportation Analysis

A number of assumptions form the basis of this analysis of transportation impacts. Section 3 of the main report presents assumptions that apply to the entire evaluation. General assumptions that are specific to this transportation analysis are discussed below. Additional assumptions that are specific to the three analysis categories described above are discussed in the corresponding parts of Section A.3 of this appendix.

In this analysis, it is assumed that all transportation of untreated and treated (processed) spent IERs on public roadways would be by truck, because this is likely to be the most common mode of transport of spent IERs. It is further assumed that all shipping casks are full when carrying spent IERs from an origin to a destination, and then always returned empty to the origin. Based on this assumption, the transportation analysis considered that the shipping casks used to transport the spent IERs from the NPPs to the waste processing facilities or waste disposal facilities and from the waste processing facilities to the waste disposal facilities, would all be returned empty to the NPPs or waste processing facilities from which they originated. The analysis also considered that separate shipping casks would be used to ship processed (blended or volume-reduced) spent IERs between the waste processing facilities and waste disposal sites.

Note, however, that in actual practice, trucks transporting shipping casks full of spent IERs from NPP origins to spent IER processing facility destinations could then transport the processed resins directly to the LLRW disposal sites rather than returning to the NPPs. In Alternatives 1A, 1B, 4A, and 4B, which involve spent IER processing (blending or volume reduction), this would reduce the total number of trips and the total number of miles driven. There is a direct relation between transportation impacts and numbers of shipments (trips) and miles driven (i.e., more trips or miles driven results in more impacts). Thus, since this transportation analysis makes the conservative assumption that full shipping casks are always transported from an origin to a destination and then return empty to the origin, the analysis overestimates the number of trips and corresponding miles driven and correspondingly conservatively estimates potential transportation impacts of the four waste processing alternatives.[3]

A.1.3 Organization of the Remainder of this Appendix

The remainder of this appendix is organized as follows:

- The estimated number of annual truck shipments of spent IERs and returned empty containers for each of the six alternatives is developed and presented in Section A.2.
- Potential transportation impacts of the six alternatives, in each of the three impact categories identified earlier, are discussed in Section A.3.
- References cited in this appendix are listed in Section A.4.

A.2 Estimated Annual Number of Truck Shipments by Alternative

The transportation analysis in this appendix is based largely on the annual number of truck shipments for each of the six alternatives. This section provides estimates of these numbers of truck shipments, as well as the methods and assumptions used to derive these estimates. The annual number of truck shipments depends on factors such as the total volume of spent IERs to be transported per year by waste classification, sizes of containers used for transport, and the number of containers that can be carried on each truck.

A.2.1 Volume and Classification of Spent IERs Generated Annually

The estimated average annual volumes of spent IERs generated by the 65 operating U.S. commercial NPPs, by waste classification, are shown in Table 2 in Section 2.1.3 of the main report. From this table, the projected average total annual volume of spent IERs generated is 2568 cubic meters (m^3) (90,620 cubic feet (ft^3)), of which 2215 m^3 (78,182 ft^3) are Class A concentration, 319 m^3 (11,258 ft^3) are Class B concentration, and 34 m^3 (1180 ft^3) are Class C concentration.

A.2.2 Spent IER Shipping Requirements

As discussed in Section 2.1.2, spent IERs are placed in High Integrity Containers (HICs) or liners at the NPPs. As discussed in Section 4.1.2, spent IERs are generally sufficiently radioactive that they must be transported in special shielded transportation containers, or casks, when shipped on public roads. The HICs or liners are placed in these casks for offsite shipment.

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[3] It was also considered that LLRW processing and disposal companies frequently are the owners of the shielded shipping casks that would be used to transport the spent IERs, and would try to use these casks as efficiently as possible. As such, these companies would most likely seek to optimize the use of their shipping casks and, therefore, would likely keep them on the move throughout the U.S. and would minimize the miles driven carrying empty casks. Thus, the NRC staff believes that the assumption in this analysis that full containers of spent IERs are always returned empty to their origins, which essentially doubles the numbers of shipments (trips) and miles driven, still results in very conservative estimates of actual transportation impacts.

The transportation container may be either a Type A or a Type B certified shipping cask, depending on the A_2 value[4] of the contents of the shipping container (10 CFR Part 71, Appendix A). If the radioactivity of the spent IERs in the HIC or liner does not exceed the A_2 value, the spent IERs can be shipped in Type A shipping casks. If the radioactivity of the spent IERs in the HIC or liner exceeds the A_2 value, the spent IERs are shipped in Type B casks. The Type A and Type B casks typically used are Chem-Nuclear Systems (CNS) 14-215 and CNS 8-120B, respectively.

Table A-1 summarizes the specifications (capacities, dimensions, and loaded weights) of the two shipping cask types. A number of different sizes of HICs or liners will fit inside each type of shipping cask (EnergySolutions 2010a; 2010b); however, this evaluation is based on the largest liner that will fit in each type of shipping cask because industry typically maximizes the volume of spent IERs shipped in each cask.

Table A-1 Specifications of Type A and Type B Shipping Casks

DIMENSIONS	TYPE A CASK[a] (CNS 14-215)	TYPE B CASK[b] (CNS 8-120B)
Capacity of the liner that fits inside the cask (L14-195 liner for Type A and L8-120 liner for Type B[c]) (m^3 (ft^3))	5.29 (187)	3.17 (112)
Total Length of Cask (m (ft))[d]	2.16 (7.09)	2.24 (7.33)
Outer Diameter of Cask (m (ft))	2.06 (6.76)	1.88 (6.17)
Maximum Loaded Weight (metric tons (tons))	26.5 (29)	29 (32)

[a] Source: EnergySolutions, 2010b.

[b] Source: EnergySolutions, 2010a.

[c] The model L14-195 and L8-120 liners are used for illustrative purposes in the evaluation. Other liner types are available for use for containing spent IERs.

[d] m = meters; ft = feet.

Truck shipments of spent IERs in Type A and Type B casks are generally transported on interstate highways, and on other primary U.S. highways where interstate highways are not available. Both Type A and Type B shipping casks are usually transported using tractor-trailer trucks with semi-detached flatbed trailers. Only one Type A or one Type B cask can be carried per truck shipment because the total weight of two or more casks, plus the weight of the tractor-trailer, would exceed the U.S. interstate system weight limit of 36 metric tons (40 tons) established by the U.S. Department of Transportation (USDOT, 1995). Although tractors pulling more than one trailer are allowed on some interstate highways (USDOT, 1995), this evaluation

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[4] The A_2 value is the maximum amount of radioactive material (measured in curies or becquerels), other than special form, Low Specific Activity (LSA), and Surface Contaminated Object (SCO) materials, permitted in a Type A package. This value is either listed in 10 CFR Part 71, Appendix A, Table A-1, or may be derived in accordance with the procedures prescribed in 10 CFR Part 71, Appendix A . (10 CFR 71.4) (See definitions of LSA and SCO materials in 10 CFR 71.4.)

conservatively assumes one trailer per tractor. Therefore, for this evaluation, it is assumed that a tractor-trailer truck would carry one Type A or one Type B shipping cask, either of which would hold one HIC or liner of spent IERs.

A.2.3 Annual Numbers of Truck Shipments

The annual number of truck shipments for each alternative is estimated using information from Sections A.2.1 and A.2.2 above. For this estimate, it is assumed that the total annual volume of spent IERs (2568 m^3 (90,620 ft^3)) would be managed under each alternative, and there would be no mix of alternatives (see Section 3.1).

For the generic, non-location-specific alternatives considered in this evaluation, the A_2 value of each HIC or liner volume to be transported is not known; therefore, information on past shipping practices is used to project the fractions of future spent IER shipments made in Type A and Type B casks. Information from EnergySolutions on actual LLRW spent IER shipments received at the Barnwell, South Carolina, LLRW disposal facility during a recent 10-year period indicates that approximately 78.5 percent of the shipments were in Type A casks and 21.5 percent were in Type B casks (Magette, 2011). As discussed in Section A.2.2, lower activity LLRW would be shipped in Type A casks and higher activity LLRW would be shipped in Type B casks. As illustrated in the discussion of Table 2 in Section 2.1.3, approximately 86 percent of the spent IERs generated annually contain Class A concentrations of radionuclides, and 14 percent contain Class B or C concentrations. These percentages correlate fairly well with the numbers reported by Magette for Type A and Type B cask shipments to the Barnwell LLRW disposal site. Thus, for the purposes of this analysis, it is reasonably assumed that all of the lower activity Class A concentration spent IERs would be shipped in Type A casks and all of the higher activity Class B and C concentration spent IERs would be shipped in Type B casks. It is also assumed that Class B and Class C concentration spent IERs could be shipped together in the same cask.

Based on the assumption that only one Type A or one Type B cask would be carried per truck shipment, the annual number of truck shipments with full casks would be the same as the annual number of cask volumes, or casks that would need to be shipped. Thus, the annual number of casks that would be shipped in each of the six alternatives is estimated based on the total annual volumes of spent IERs, by waste classification, that would need to be transported in each shipment step[5] of each alternative divided by the volume of the appropriate HIC or liner for each cask type (shown in Table A-1).

However, the following base calculations were first done to estimate the total number of shipping casks volumes of each type that could be filled annually by the 65 NPPs. These numbers of cask volumes would be the same as the numbers of shipping casks of each type that could be filled and potentially shipped from the NPPs. Estimated annual spent IER volumes

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[5] Examples of “shipment steps” in the various alternatives include shipment of spent IERs from the NPPs to a waste processing facility and shipment of spent IERs from a waste processing facility to a waste disposal facility.

from Section A.2.1 and liner volumes by cask type from Table A-1 were used in these calculations, as follows (with results are rounded to the nearest whole number):

- To estimate the annual number of Type A cask volumes that could be filled by the NPPs, the total annual volume of Class A concentration spent IERs is divided by the capacity of the liner that fits in the Type A cask, i.e., 2215 m^3/year (Class A) ÷ 5.29 m^3 (Type A cask) ≈ 419 Type A cask volumes/year.

- To estimate the annual number of Type B cask volumes that could be filled by the NPPs, the total annual volume of Class B and C concentration spent IERs is divided by the capacity of the liner that fits in the Type B cask, i.e., [319 m^3/year + 34 m^3/year (Class B and C)] ÷ 3.17 m^3 (Type B cask) ≈ 111 Type B cask volumes/year.

Based on these foundation calculations and on applicable assumptions stated above and in the main report, the number of spent IER shipments annually for each alternative is estimated as follows:

- Alternative 1A—Disposal of Blended Class A, B, and C Spent IER LLRW from a Central Processing Facility (using Mechanical Mixing): There would be 530 spent IER shipments from the NPPs to the central processing (blending) facility (419 Type A and 111 Type B cask shipments) and 530 casks returning empty to the NPPs, for a total of 1060 shipments annually. After processing, since the blended Class A, B, and C concentration spent IERs would have Class A status, all shipments from the blending facility to the disposal facility could be in Type A casks. Also, since the blending process in this alternative uses a mechanical mixing process that does not appreciably affect the waste volume (see Section 4.2.1), the volume of the processed spent IERs coming out of the blending facility would be approximately the same as the volume of untreated spent IERs coming into the blending facility from the NPPs, i.e., 2568 m^3. Therefore, 485 Class A LLRW spent IER shipments (2568 m^3 ÷ 5.29 m^3 per Type A cask shipment) would travel from the processing facility to the disposal facility, and 485 would return empty to the blending facility, for a total of 970 shipments annually. Thus, there would be a total of 2030 shipments annually in this alternative (1060 shipments + 970 shipments).

- Alternative 1B—Disposal of Blended Class A, B, and C Spent IER LLRW from a Central Processing Facility (using Thermal Processing): The blending process in this alternative uses a thermal treatment process that would not reduce or otherwise appreciably change the volume of the spent IERs (see Section 4.2.2). Therefore, since Alternatives 1A and 1B are essentially the same except for the blending process used, the number of annual shipments and cask types used for Alternative 1B would be the same as for Alternative 1A, i.e., 2030 shipments annually.

- Alternative 2—Direct Disposal of Class A, B, and C Spent IER LLRW: There would be 530 shipments from the NPPs directly to the disposal facility (419 Type A and 111 Type B cask shipments) and 530 casks returning empty to the NPPs, for a total of 1060 shipments annually.

- <u>Alternative 3—Long-term Onsite Storage of Class B and C Concentration Spent IERs, then Disposal</u>: As discussed in Section 4.2.4, Alternative 3 is divided into three separate and distinct stages over time—(1) “Years 1-20”, (2) “Year 21”, and (3) ”After Year 21”.

    - *<u>Years 1-20</u>*--As discussed in Section 4.2.4, all Class A concentration spent IERs would have a disposal pathway and would be shipped for direct disposal. The Class B and C concentration spent IERs would be placed in long-term storage at the NPP sites for 20 years awaiting disposal. Thus, there would be 419 “immediate”, direct annual shipments of Class A LLRW spent IERs from the NPPs to the Class A disposal facility in Type A casks and 419 returning empty, for a total of 838 shipments annually over the 20-year period of storage of the Class B and C concentration resins. With regard to the Class B and C concentration spent IERs, there would be 111 cask volumes of these resins generated annually. Therefore, 2220 cask volumes of this waste would accumulate in storage over the entire 20-year storage period.

    - *<u>Year 21</u>*--At the conclusion of the 20 years of accumulation, it is assumed for this evaluation that all 2220 cask volumes of stored Class B and C concentration spent IERs would be shipped to a disposal facility in the twenty-first year. Also in that twenty-first year, there would be an additional 111 cask volumes of Class B and C concentration spent IERs generated. Those plus the 2220 cask volumes in storage, for a total of 2331 cask volumes of Class B and C concentration spent IERs, would be shipped to the disposal facility in Type B casks, and 2331 casks would return empty, for a total of 4664 shipments in the twenty-first year. There would also be 419 shipments of Class A LLRW spent IERs in Type A casks to the disposal facility and 419 returning empty, for a total of 838 shipments. Thus, there would be an overall total of 5500 shipments to/from the disposal facility (4662 (Type B) + 838 (Type A)) in the twenty-first year.

        (<u>**NOTE**</u>**:** The assumption that there would be 5500 total shipments in the twenty-first year, with 4662 of these in Type B casks (2331 full and 2331 empty), is likely a considerable overestimation of what would happen in actual practice, due largely to the limited number of Type B shipping casks that would be expected to be available at the time. This premise is based on there currently (early 2012) being only four Type B casks available in the U.S. for shipping the majority of Class B and C LLRW (i.e., the majority of all Class B and C LLRW, not only the spent IERs that comprise a small fraction of the total U.S. LLRW annually (see Section 2.1.3)) (Herness, 2012a). Assuming 250 workdays per year (based on 50 work weeks/year x 5 workdays/week = 250 workdays), there would need to be an average of 9 to 10 shipments per day (2331 cask volumes/year ÷ 250 workdays/year) every workday for a year to ship all 2331 cask volumes of Class B and C LLRW spent IERs in Type B casks in the twenty-first year. However, with the four Type B casks currently available, there presently could be at most only four spent IER shipments per day if the available Type B casks were used solely for Class B and C LLRW spent IER shipments. Again, however, these

Type B casks would also be needed to ship other types of Class B and C LLRW generated annually in the U.S. Further, even if industry were to double the number of Type B casks as is currently planned (Herness, 2012a), and even if shipments were made 365 days a year, it would still not be possible to ship the entire 2331 cask volumes of Class B and C LLRW spent IERs in a single year.

Instead, it would reasonably be expected to take several years to accomplish. Nevertheless, for simplicity, the analysis in this appendix very conservatively assumes there would be 4662 Type B cask shipments, and 5500 Type A and Type B cask shipments, in the twenty-first year of Alternative 3. This assumption is necessary and justifiable because there is no way to predict, or speculate on, how many Type B casks would actually be available for Class B and C LLRW spent IER shipments following the 20-year storage period or how many years it would actually take to ship all of the stored Class B and C wastes from the NPPs for disposal. Thus, again, the assumption that all of the Class B and C concentration spent IERs would be shipped for disposal in twenty-first year clearly results is a substantial overestimate of the transportation impacts in Year 21 of Alternative 3; and in reality, the impacts would most likely be significantly less than are estimated in this appendix. This makes the Alternative 3 in Year 21 scenario a special case, or outlier, in relation to all of the other transportation scenarios evaluated in this report for the six alternatives.)

  - *<u>After Year 21</u>*--Starting in the twenty-first year and thereafter, the NPPs would be able to ship all of their B and C LLRW spent IERs for direct disposal, in addition to their Class A LLRW resins. Therefore, the period after Year 21 of Alternative 3 would be identical to and would have the same annual numbers of Type A and Type B casks shipments as Alternative 2. Again, this assumes that all of the stored Class B and C concentration spent IERs are shipped for disposal from the 65 NPPs in the twenty-first year. However, note that the potential transportation impacts of Alternative 3 after Year 21 are not separately estimated herein because those impacts would be identical to those of Alternative 2.

- <u>Alternative 4A—Volume Reduction of Class B and C Concentration Spent IERs at a Processing Facility, Long-term Storage, then Disposal</u>: There would be 419 “immediate” annual Class A concentration spent IER shipments in Type A casks from the NPPs to the disposal facility and 419 returning empty, for a total of 838 shipments annually. Also, there would be 111 Class B and C concentration spent IER shipments in Type B casks annually to the processing (volume reduction) facility and 111 returning empty to the NPPs, for a total of 222 Class B and C shipments annually. As discussed in Section 4.2.5, the volume reduction process would decrease the volume of the spent IERs by a factor of approximately five. Thus, for every 111 Type B casks of Class B and C concentration spent IERs shipped to the processing facility, about 23 Type B casks of processed (volume-reduced) spent IERs would result (i.e., 111 ÷ 5 ≈ 23). Therefore, under the scenario in which the volume-reduced Class B and C concentration wastes are shipped to the waste disposal site and stored there for 20 years prior to disposal, there would be 23 shipments annually from the processing facility to the long-term storage site and 23 shipments returning empty to the processing facility, for a total of 46 annual shipments. Thus, the total number of annual shipments under this alternative would be 1106 (838 + 222 + 46).

- Alternative 4B—Volume Reduction of Class B and C Concentration Spent IERs at a Processing Facility, then Disposal: For this alternative, the total number of annual shipments would be the same as under Alternative 4A, i.e., 1106. The only difference between the two alternatives is the volume-reduced waste long-term storage step at the waste disposal site in Alternative 4A prior to waste disposal. Thus, the number of shipments between the NPPs and the disposal facility for Class A LLRW spent IERs (828), and between the NPPs and processing (volume reduction) facilities for Class B and C concentration spent IERs (222), would be the same. In addition, since the volume reduction process used would be the same as in Alternative 4A, there would also be 46 Type B cask shipments annually to and from the waste disposal site (though for direct disposal rather than long-term storage of the wastes).

Table A-2 presents a summary of the annual number of truck trips estimated above.

Table A-2 Annual Number of Truck Shipments by Alternative

ALTERNATIVE	**ANNUAL NUMBER OF TRUCK SHIPMENTS**			
	NPPs to/from Processing Facility	**Processing Facility to/from Disposal Facility**	**NPPs to/from Disposal Facility**	**Total Trips**
1A	1060	970	N/A[a]	2030
1B	1060	970	N/A	2030
2	N/A	N/A	1060	1060
3 (Years 1-20)[b]	N/A	N/A	838	838
3 (Year 21)[b]	N/A	N/A	5500	5500
3 (After Year 21)[b,c]	N/A	N/A	1060	1060
4A	222	46	838	1106
4B	222	46	838	1106

[a] N/A = not applicable.

[b] See text above for explanation of the three stages of Alternative 3.

[c] Potential transportation impacts of Alternative 3 after Year 21 are not separately estimated in this report because those impacts would be identical to those of Alternative 2 (see text).

A.3 Potential Transportation Impacts

The three categories of potential transportation impacts identified earlier are evaluated in this section. The section includes a discussion of assessment methodologies, assumptions, and results. The three transportation impact categories are:

- Impacts on local and national traffic (Section A.3.1);
- Radiological impacts of routine transportation (Section A.3.2); and
- Non-radiological and radiological impacts of transportation accidents (Section A.3.3).

Although quantitative estimates of potential transportation impacts are calculated, impacts are also assessed qualitatively, using the significance levels of SMALL, MODERATE, or LARGE discussed in Section 3.2 of the main report.

It is important to note that for the Alternative 3 in “Year 21” spent IER transportation scenario (described in Section 4.2.4 of the main report), potential transportation impacts are estimated and reported in this section for the sake of completeness only. Those potential impacts are neither discussed at any length in the text of this appendix nor mentioned at all in the corresponding discussions of potential transportation impacts in the main report. This is because, for the justifiable reasons detailed in the NOTE in Section A.2.3, the potential transportation impacts of the Alternative 3 in Year 21 scenario are substantially overestimated in this report; therefore, this scenario is fundamentally a special case, or outlier, in relation to all of the other transportation scenarios evaluated for the six alternatives. Thus, elaboration on potential transportation impacts for this scenario, or comparison of those impacts with those of the other alternatives, would not be representative of actual practice.

A.3.1 Impacts on Local and National Traffic

In this section, potential impacts on local and national traffic from the transportation of the spent IERs (full and empty casks) are evaluated, as discussed in Sections A.3.1.1 and A.3.1.2, respectively.

A.3.1.1 Impacts on Local Traffic

The impacts on local traffic near spent IER processing facilities (for blending or volume reduction) and LLRW disposal facilities, from trucks carrying spent IERs and empty shipping casks, are evaluated using the estimated numbers of annual truck shipments shown in Table A-2 in Section A.2.3 for each alternative. Trucks would enter and leave these facilities only during their normal working hours. Thus, for this analysis, the annual numbers of shipments (trips) for each of the alternatives are divided by the number of operating hours per year for a waste processing or disposal facility (assumed 2000 hours per year, based on fifty 40-hour workweeks). This gives an average number of trucks per hour on local roads entering and leaving these facilities.

The numbers of trucks per hour on local roads, for each of the six alternatives, is estimated as described below:

- Alternatives 1A and 1B: As shown in Section A.2.3, the numbers of trips between the various origins and destinations in these two alternatives would all be the same. In each of these alternatives, there would be a total of 2030 truck shipments per year going to, and returning from, the central processing (blending) facility (1060 truck shipments between the NPPs and the processing facility plus 970 shipments between the processing facility and waste disposal facility). From this, for the 2000 hours per year during which each type of facility is assumed to be operating, there would be an average of about one additional truck per operating hour on local roads near the processing facility, i.e., 2030 trucks/year ÷ 2000 hours/year = 1.02 trucks/hour. In addition, there would be 970 truck shipments per year going to, and returning from, the disposal facility. Thus, there would be an average of about one truck every two operating hours traveling locally near the waste disposal site, i.e., 970 trucks/year ÷ 2000 hours/year = 0.49 truck/hour). One additional truck per operating hour on local roads near the processing facility, and one additional truck every two hours on local roads near the disposal facility, would represent very small additions to local truck traffic volumes and even smaller additions to overall traffic volumes and, therefore, SMALL impacts on local traffic near these facilities.

- Alternative 2: There would be 1060 truck shipments per year going to, and returning from, the waste disposal facility. This equates to an average of about one truck every two operating hours (1060 trucks/year ÷ 2000 hours/year = 0.53 trucks/hour) traveling on local roads near the disposal facility. One additional truck per two operating hours would represent a SMALL impact on local traffic near the waste disposal site.

- Alternative 3: For Years 1-20, there would be 838 truck shipments per year going to, and returning from, the waste disposal facility. This would result in an average of about one additional truck every 2.5 operating hours (838 trucks/year ÷ 2000 hours/year = 0.42 trucks/hour) traveling on local roads near the waste disposal facility and a correspondingly SMALL impact on local traffic. In Year 21, there would be a total of 5500 truck shipments going to, and returning from, the disposal facility, or an average of about three additional trucks per hour (5500 trucks/year ÷ 2000 hours/year = 2.75 trucks/hour) traveling locally. Although as discussed in Section A.2.3, 5500 truck trips in Year 21 represents a substantial overestimate, even three additional trucks per hour would represent a SMALL impact when compared to the average of 75 trucks per hour at an LLRW disposal facility discussed above. As discussed in Section A.2.3, the potential impact after Year 21 would be the same as that estimated for Alternative 2.

- Alternatives 4A and 4B: As shown in Section A.2.3, the numbers of trips between the various origins and destinations in these two alternatives would all be the same. Thus, in both of these alternatives, there would be a total of 268 truck shipments per year going to, and returning from, the thermal processing (volume reduction) facility (i.e., 222 trips between the NPPs and the processing facility and 46 between the processing facility and

> the waste disposal site). This would result in an average of a little more than about one truck per 8-hour operating day traveling on local roads near the waste processing facility (i.e., 268 trucks/year ÷ 2000 hours/year = 0.14 trucks/hour). In addition, there would be 884 trucks per year traveling to and from the waste disposal site (838 trips between the NPPs and the waste disposal site and 46 trips between the processing facility and the disposal site). This would result in an average of a little less than one truck every two operating hours traveling locally near the disposal site (i.e., 884 trucks/year ÷ 2000 hours/year = 0.44 trucks/hour). Less than one additional truck per 8-hour operating day traveling locally near the waste processing facility and less than one additional truck every two operating hours near the waste disposal site would represent SMALL impacts on local traffic near these facilities.

Table A-3 presents a summary of the average numbers of additional trucks on local roads near spent IER processing and waste disposal facilities estimated above. The results demonstrate that spent IER shipments (full and empty casks) would add little to existing local traffic near the waste processing and disposal facilities in all six alternatives. Therefore, transportation of spent IERs in all six alternatives would have SMALL impacts on local traffic near these facilities, and correspondingly SMALL impacts on local traffic congestion, air quality, noise levels, and road surface wear.

Table A-3 Estimated Additional Numbers of Trucks on Local Roads near Spent IER Processing and Disposal Facilities by Alternative

ALTERNATIVE	ADDITIONAL TRUCKS NEAR WASTE PROCESSING FACILITY[a]	ADDITIONAL TRUCKS NEAR WASTE DISPOSAL SITE[a]
1A	1 per operating hour	1 every 2 operating hours
1B	1 per operating hour	1 every 2 operating hours
2 and 3 (After Year 21)	N/A[b]	1 every 2 operating hours
3 (Years 1-20)	N/A	1 every 2.5 operating hours
3 (Year 21)	N/A	3 per operating hour
4A	1 per 8-hour operating day	1 every 2 operating hours
4B	1 per 8-hour operating day	1 every 2 operating hours

[a] Based on an 8-hour operating day.

[b] N/A = not applicable.

A.3.1.2 Impacts on National Traffic

Potential traffic impacts on a national level, from truck shipments of spent IERs and empty casks, are evaluated by comparing the total annual weight of these shipments in each alternative to the total annual weight of all U.S. freight transported by tractor-trailer trucks. The annual number of tractor-trailer truck trips per year in the U.S., or of total trips per year for vehicles of all types, is not recorded. Therefore, it is not possible to compare the number of spent IER and empty cask truck shipments from Table A-2 to the annual total number of tractor-trailer trips or total number of vehicle trips.

The Bureau of Transportation Statistics of the USDOT provides data on the total annual weight of U.S. freight transported by tractor-trailer trucks in the U.S., 1.13×10^{10} metric tons per year (1.25×10^{10} tons per year) (USDOT, 2011; Table 3-1). From Table A-1 in Section A.2.2, the Type A cask (CNS 14-215) and Type B cask (CNS 8-120B) have maximum loaded weights of 26.5 metric tons (29 tons) and 29 metric tons (32 tons), respectively. For the purposes of this specific evaluation, the full and empty casks are conservatively assumed to have the same maximum loaded weights, as shown above, which results in a conservative estimate of the potential impact the spent IER shipments would have on national traffic. This assumption is necessary because the weights of the HICs or liners containing spent IERs that are within the Type A and Type B shipping casks can be highly variable and, therefore, cannot be estimated with certainty.

Table A-4 presents the estimated annual shipment weights for each of the six alternatives and their percentages of the total annual U.S. tractor-trailer shipment weight. The numbers of shipments by shipping cask type in this table are calculated using the information developed in Section A.2.3. As shown in Table A-4, the spent IER shipments would account for a very small percentage of the annual national (freight) traffic on U.S. highways, ranging from 0.0002 percent for Alternative 3 (Years 1-20) to 0.0005 percent for Alternatives 1A and 1B. Note that these percentages would be even smaller (negligible) if all other vehicular traffic (e.g., cars, vans, buses, light trucks, etc.) were considered in the calculations. Thus, the effect of spent IER shipments under any of the alternatives on national traffic and on associated traffic congestion, air quality, noise levels, and road surface wear would be SMALL.

A.3.2 Radiological Impacts of Routine Transportation

Potential radiological impacts from routine, incident-free transportation of spent IERs in Type A and Type B shipping casks are evaluated for individual receptors and for populations in Sections A.3.2.1 and A.3.2.2, respectively. Potential impacts are assessed for various scenarios involving moving and stationary trucks. Individual receptors are persons at various locations along transportation routes traveled by trucks carrying radioactive materials (e.g., spent IERs from NPPs). Populations are groups of residents along the transportation routes.

During routine transportation, external radiation from the shipping containers used to transport radioactive materials, such as the spent IERS from NPPs, is the source of the radiation dose to the various potential receptors. In this evaluation, potential radiological impacts due to possible

Table A-4 Annual Spent IER Truck Shipments as Percentages of Total U.S. Tractor-Trailer Truck Shipments, Based on Freight Weights

ALTERNATIVE	SPENT IER TRUCK SHIPMENTS PER YEAR BY SHIPPING CASK TYPE[a]		ANNUAL SPENT IER SHIPMENT WEIGHT (TONS)[b]	SPENT IER SHIPMENT WEIGHT AS % OF TOTAL TRACTOR-TRAILER FREIGHT WEIGHT[c]
	Type A Casks (CNS 14-215)	Type B Casks (CNS 8-120B)		
1A	1808	222	59,536	0.0005%
1B	1808	222	59,536	0.0005%
2 and 3 (After Year 21)	838	222	31,406	0.0003%
3 (Years 1-20)	838	0	24,302	0.0002%
3 (Year 21)	838	4664	173,486	0.001%
4A	838	268	32,878	0.0003%
4B	838	268	32,878	0.0003%

[a] For shipments of both full and empty casks.

[b] Calculated by multiplying the numbers of CNS 14-215 (Type A) cask shipments by 29 tons and of CNS 8-120B (Type B) cask shipments by 32 tons (from Table A-1).

[c] Calculated by dividing the annual spent IER shipment weights in tons by the total annual U.S. tractor-trailer shipment weight of 1.25 x 10^{10} tons (USDOT, 2010).

exposures of various individual human receptors to this external radiation, in terms of doses of radiation in millisieverts (mSv) (or millirem (mrem)), are estimated using the RADTRAN 6 model (Weiner et al., 2009) (hereafter called the “RADTRAN model” or “RADTRAN”). For a radiation dose to a population, RADTRAN calculates the “collective dose” (expressed in units of person-mSv[6]) by integrating the average radiation dose over the area occupied by the population. RADTRAN is the nationally accepted, standard computer program for calculating the risks of transporting radioactive materials. RADTRAN has been used to calculate radiological risks of transporting radioactive materials in U.S. environmental assessments and EIS's since 1977 and internationally since the mid-1980s. RADTRAN includes modules for use in modeling radiological impacts of routine transportation and of transportation accidents. The former is used in evaluating potential impacts in this section, and the latter is used in Section A.3.3. The RADTRAN model has been validated using field measurements (Steinman et al., 2002).

In modeling radiological impacts from routine transportation, RADTRAN models the external radiation dose rate from the shipping cask as if the radiation were emitted from a point source located where the center of the cask would be (radiation dose rate, or dose rate, is the radiation

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[6] Person-mSv is a unit of dose that represents an individual dose integrated over an area that is occupied by a population. It can be thought of as an average individual dose multiplied by the number of people over which it is averaged.

dose per unit time, expressed as mSv per hour (or mrem per hour)). RADTRAN sets the intensity of this point source equal to the Transport Index (TI) of the cask, which is defined as the dose rate measured at a distance of 1 meter (m) (3.3 feet (ft)) from the lateral surface of the cask.[7] To a receptor located far from the cask, the radiation dose received from such a point source would be indistinguishable from that received from the actual cask. It has been shown that the dose calculated by the RADTRAN approximation overestimates the measured dose by a few percent (Steinman et al., 2002).

Furthermore, when the actual external radiation dose rate from the shipping cask is not specifically known, as is the case for the Type A and Type B shipping casks containing spent IERs in this evaluation, the maximum external dose rate for a shipping container allowed by NRC regulation is used in RADTRAN to assess radiation doses to individuals and populations. NRC regulations allow shipping containers, or casks, that hold radioactive materials to emit minor amounts of ionizing radiation from the external cask surfaces. The Type A and Type B casks used to transport spent IERs, as all containers certified for use to transport radioactive materials, must meet the NRC standard for external radiation during normal transport. In the case of flat-bed style trucks (such as those used to transport casks of spent IERs), 10 CFR 71.47(b)(3) states that the dose rate from this external radiation must not exceed 0.1 mSv per hour (10 mrem per hour) at 2 m (6.6 ft) from the vertical planes projected by the outer edges of the trailer carrying the cask. Compliance with this regulation is guaranteed by appropriate cask shielding design, package content limitations, and inspections. Basing the RADTRAN modeling on this maximum, legally allowable dose rate is conservative because actual dose rates from shipping casks would generally be much lower than the allowable limit.

In the sections that follow, potential radiological impacts to individual receptors and populations are estimated, expressed as radiation doses in mSv. The radiation doses from the various alternatives are estimated based on annual numbers of spent IER shipments; therefore, these estimated doses are the doses from exposures over a period of one year. Thus, to put the annual doses to individuals in perspective, they are compared with the average annual U.S. background dose of 3.6 mSv/year (360 mrem/year) (Shleien et al., 1998), as a percentage of this background dose. For populations, the annual collective dose is compared to 3.6 mSv multiplied by the affected population, since each member of the population sustains this annual average background dose. The use of the annual U.S. background radiation level allows for the assumption that the background level would be the same for all receptors. In addition, from the estimated radiation doses, the corresponding probabilities of fatal cancers resulting from exposure to these radiation doses, or latent cancer fatalities (LCFs), are derived. Specifically, LCFs are the expected number of additional cancer fatalities that may occur during the lifetime of individuals, because of (or latent to) an exposure to ionizing radiation. LCF risk values are derived by multiplying the dose by a conversion factor, 6×10^{-5} LCF per mSv (ISCORS, 2002).

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[7] Transport Index (TI) is defined as the dose rate at 1 meter from a vertical plane perpendicular to the side of the trailer carrying the cask (NRC, 2012). RADTRAN does not account for the offset between the cask and trailer.

The calculated LCFs are also expressed as a fraction (percentage) of 2010 total estimated cancer fatalities in the U.S. of 569,495 (American Cancer Society, 2010; p. 4).[8]

A.3.2.1 Impacts on Individual Receptors

Potential radiological impacts are calculated using RADTRAN for the following types of individual receptors:

- Individual maximally exposed to a moving truck (maximally exposed individual, or MEI)
- Average person along the transportation route: rural–suburban
- Average person along the transportation route: urban
- Average resident near a truck stop: rural–suburban

The MEI shown above is the individual receiving the maximum exposure to a moving truck carrying a radioactive cargo. The MEI is modeled as a person standing as close as possible (30 m from the center of the highway) to the moving truck, when the truck is moving slowly (about 24 kilometers per hour (kph) (15 miles per hour (mph)), past the MEI. This slow speed is possibly from a traffic jam, road construction, or bad weather.

Truck stops would be for rest and refueling. Truck stops are not modeled in urban areas because stops used by trucks carrying radioactive materials would generally be away from heavily populated areas.

Tables A-5 and A-6 identify (and define) the input parameters, by cask type, used in the RADTRAN model for the evaluation of the potential radiological impacts of routine (incident-free) transportation on individuals.[9] These parameters are the same for all six alternatives. The parameters in Table A-6 are specifically used to evaluate the potential radiological impacts to individuals living near truck stops.

Potential radiological impacts to individuals (in terms of radiation doses) calculated using RADTRAN are first estimated for one routine shipment of spent IERs of each cask type (full casks). The results of those calculations are then used to estimate the potential radiological impacts to individuals from all routine shipments per year for each of the six alternatives. Return trips are not modeled because there would be negligible or no radiological impacts from routine shipments of empty casks.

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[8] 2010 total estimated cancer fatalities in the U.S. derived by the American Cancer Society from U.S. mortality data, 1969-2007.

[9] Note that the RADTRAN user interface also lists a number of default parameter values (e.g., breathing rate).

Table A-5 RADTRAN Input Parameters for Calculating Radiation Doses to Individual Receptors from Routine Transportation

INPUT PARAMETERS	Type A Cask (CNS 14-215)	Type B Cask (CNS 8-120B)
Cask/vehicle longest dimension (m (ft)): shipping cask and vehicle (the trailer of a tractor-trailer truck) are modeled to have the same longest external dimensions[a]	2.16 (7.09)	2.24 (7.35)
Cask/vehicle dose rate at 1 meter from the cask (mSv/hour (mrem/hour)): calculated from the NRC regulatory maximum of 0.1 mSv/hour (10 mrem/hour) at 2 meters from the cask (10 CFR 71.47(b)(3))	0.146 (14.6)	0.142 (14.2)
Gamma fraction: fraction of external radiation from the cask that is gamma radiation	1	1
Neutron fraction: fraction of external radiation from the cask that is neutron radiation	0	0
Rural and suburban vehicle speed (kph (mph))	108 (67)	108 (67)
Urban vehicle speed (kph (mph))	102 (63)	102 (63)
Maximally exposed individual (MEI) distance from vehicle (m (ft))	30 (98)	30 (98)
Vehicle speed past MEI (kph (mph))	24 (15)	24 (15)
Minimum distance to nearest resident (m (ft))[b]	30 (98)	30 (98)
Maximum distance to nearest resident (m (mile))[c]	800 (0.50)	800 (0.50)
Rural shielding factor[d]	1	1
Suburban shielding factor[d]	0.87	0.87
Urban shielding factor[d]	0.018	0.018

[a] In order to accommodate the RADTRAN spherical model, the longest cask dimension and the vehicle length are assumed to be the same. This assumption is valid because any additional trailer length beyond the cask does not change the radiation dose to the public, because the affected public is in a direction perpendicular to the radiating cask and not behind it.

[b] The distance from the center of a six-lane interstate highway to the outer edge of the shoulder is at least 22 m (FHWA, 2012). The nearest residence is usually 10 m further from the highway.

[c] The dose to a resident along the route is proportional to $1/r^2$. The dose at 1600 m (1 mile) is not significantly different from the dose at 800 m; therefore, 800 m is the default value in RADTRAN.

[d] The shielding factor is the inverse of the fraction of energy transmitted; i.e., a shielding factor of 1 means that all energy from the source is transmitted and there is no shielding. The rural, suburban, and urban shielding factors are based on the following assumptions: rural residents spend a great deal of time out of doors, with no shielding; suburban residents live in wood or stucco houses and have a small amount of shielding; and urban residents live in brick or concrete block buildings and are heavily shielded (Neuhauser et al., 2000).

Table A-6 Additional RADTRAN Input Parameters for Calculating Radiation Doses to Individual Receptors near Truck Stops

INPUT PARAMETERS	Type A Cask (CNS 14-215)	Type B Cask (CNS 8-120B)
Average time at stop (hours)	0.33	0.33
Minimum distance of a nearby resident from the truck at the stop (m (ft))	30 (98)	30 (98)
Maximum distance of a nearby resident from the truck at the stop (m (mile))	800 (0.50)	800 (0.50)
Stop due to a truck accident (hours): only in which there is no release of radioactive material	10	10

A.3.2.1.1 Impacts to Individuals from One Routine Shipment

Table A-7 shows the estimated radiological impacts to the various types of individual receptors from one routine shipment of spent IERs, for both the Type A and the Type B cask (full casks), including estimated doses and LCFs (calculated as described earlier). For completeness, comparisons with U.S. annual average background dose and 2010 total estimated U.S. cancer fatalities are shown; however, these results are not discussed, as the purpose of Table A-7 is to provide data for use in later calculations in this appendix. Note that the results for the average resident near the rural and suburban truck stops are the equivalent.

A Note about Exponential Notations Used in This Appendix

Numbers in this appendix with exponential notations are shown in two different ways, in one way in text and in an equivalent (though different looking) way in certain tables. For example, the number 0.000053 can be expressed exponentially in either one of the two ways—as the more familiar 5.3×10^{-5} (as shown in the text) or as 5.3E-05 (as shown in tables). The reason for this is that Microsoft Excel® is used to generate many of the results tables in this appendix, and that software uses the “E” notation.

A.3.2.1.2 Impacts to Individuals from All Routine Shipments by Alternative

The total annual doses and corresponding LCFs from all spent IER shipments (full casks) by alternative, to the various types of individual receptors by cask type, are shown in Table A-8. The total annual doses in this table are calculated by multiplying the dose from a single shipment (from Table A-7) by the annual number of shipments carrying spent IERs for each cask type (full casks), which is half of the number of shipments shown in Table A-4. The total annual doses by cask type are then added to show the collective doses for all spent IER shipments by alternative. This approach is based on the conservative assumptions that (1) each individual receptor is exposed to every spent IER shipment for a given alternative[10], and (2) the doses from exposures to multiple shipments are additive.[11] Thus, actual exposures would be lower than are estimated in this evaluation. Table A-8 also shows the collective dose results as percentages of U.S. average annual background doses. In addition, Table A-8 shows the corresponding LCFs (calculated as discussed earlier), and compares them, as a percentage, to the American Cancer Society 2010 estimated U.S. cancer fatalities data.

Table A-7 Estimated Radiological Impacts to Individual Receptors from a Single Routine Spent IER Shipment

RECEPTOR	CASK TYPE	DOSE (mSv)	DOSE AS % U.S. ANNUAL BACKGROUND[a]	LCF	LCF AS % 2010 ESTIMATED U.S. CANCER FATALITIES[b]
Maximally exposed individual (MEI)	A	2.4E-06	1E-05%	1.5E-10	3E-14%
	B	2.4E-06	1E-05%	1.5E-10	3E-14%
Average person along the route: rural	A	1.2E-09	3E-8%	7.3E-14	1E-17%
	B	1.2E-09	3E-8%	7.4E-14	1E-17%
Average person along the route: suburban	A	1.1E-09	3E-8%	6.7E-14	1E-17%
	B	1.1E-09	3E-8%	6.8E-14	1E-17%
Average person along the route: urban	A	2.3E-11	7E-10%	1.4E-15	3E-19%
	B	2.3E-11	7E-10%	1.4E-15	3E-19%
Average resident near truck stop: rural	A	4.3E-06	1E-04%	2.6E-10	5E-14%
	B	4.3E-06	1E-04%	2.6E-10	5E-14%
Average resident near truck stop: suburban	A	4.3E-06	1E-04%	2.6E-10	5E-14%
	B	4.3E-06	1E-04%	2.6E-10	5E-14%

[a] Average annual U.S. background dose = 3.6 mSv/year (Shleien et al., 1998).

[b] Based on 2010 total estimated U.S. cancer fatalities of 569,495 (American Cancer Society, 2010).

As shown in Table A-8, the MEI would receive the highest radiation doses from moving trucks and residents near truck stops would receive the highest doses overall. However, the radiological impacts of the alternatives would be similar to each other. Radiation doses and LCFs to all individuals from all of the shipments of spent IERs for each of the alternatives would generally be small to negligible percentages of the average annual background dose sustained by the individual receptor and of the 2010 total estimated U.S. cancer fatalities, respectively. The doses range from approximately 3 x 10^{-7} to 1.2 x 10^{-1} percent of annual background, and would thus be representative of SMALL impacts to individual receptors. This conclusion is

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[10] In actual practice, this would not occur since not all individuals would be located in the same place at the same time over a period of one year.

[11] In reality, multiple radiation doses over time are not additive. For example, in calculating medical therapeutic and diagnostic doses, the patient's prior history of radiation exposure is not usually considered or summed (Shleien et al., 1998; Chapter 10).

Table A-8 Estimated Radiological Impacts to Individual Receptors from All Routine Spent IER Shipments for Each Alternative

RECEPTOR	CASK TYPE	TOTAL ANNUAL DOSE (mSv) FROM ALL SPENT IER (FULL CASK) SHIPMENTS BY ALTERNATIVE					CASK TYPE	TOTAL ANNUAL LCF FROM ALL SPENT IER (FULL CASK) SHIPMENTS BY ALTERNATIVE				
		1A and 1B	2 and 3 (After Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B		1A and 1B	2 and 3 (After Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B
Maximally exposed individual (MEI)	**A**	2.2E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03	**A**	1.3E-07	6.1E-08	6.1E-08	6.1E-08	6.1E-08
	B	2.7E-04	2.7E-04	N/A	6.7E-03	3.3E-04	**B**	1.6E-08	1.6E-08	N/A	4.0E-07	2.0E-08
	A + B	2.5E-03	1.3E-03	1.0E-03	7.7E-03	1.3E-03	**A + B**	1.5E-07	7.7E-08	6.1E-08	4.6E-07	8.1E-08
	A+B % U.S. Annual Background	***7E-02%***	***4E-02%***	***3E-02%***	***2E-01%***	***4E-02%***	***A+B % 2010 Estimated U.S. Cancer Fatalities***	***3E-11%***	***1E-11%***	***1E-11%***	***8E-11%***	***1E-11%***
Average person along route: rural	**A**	1.1E-06	5.1E-07	5.1E-07	5.1E-07	5.1E-07	**A**	6.6E-11	3.1E-11	3.1E-11	3.1E-11	3.1E-11
	B	1.4E-07	1.4E-07	N/A	3.4E-06	1.7E-07	**B**	8.2E-12	8.2E-12	N/A	2.0E-10	9.9E-12
	A + B	1.2E-06	6.5E-07	5.1E-07	3.9E-06	6.8E-07	**A + B**	7.4E-11	3.9E-11	3.1E-11	2.3E-10	4.1E-11
	A+B % U.S. Annual Background	***3E-05%***	***2E-05%***	***1E-05%***	***1E-04%***	***2E-05%***	***A+B % 2010 Estimated U.S. Cancer Fatalities***	***1E-14%***	***7E-15%***	***5E-15%***	***4E-14%***	***7E-15%***
Average person along route: suburban	**A**	1.0E-06	4.7E-07	4.7E-07	4.7E-07	4.7E-07	**A**	6.1E-11	2.8E-11	2.8E-11	2.8E-11	2.8E-11
	B	1.3E-07	1.3E-07	N/A	3.1E-06	1.5E-07	**B**	7.5E-12	7.5E-12	N/A	1.9E-10	9.1E-12
	A + B	1.1E-06	6.0E-07	4.7E-07	3.6E-06	6.2E-07	**A + B**	6.9E-11	3.6E-11	2.8E-11	2.2E-10	3.7E-11
	A+B % U.S. Annual Background	***3E-05%***	***2E-05%***	***1E-05%***	***1E-04%***	***2E-05%***	***A+B % 2010 Estimated U.S. Cancer Fatalities***	***1E-14%***	***6E-15%***	***5E-15%***	***4E-14%***	***6E-15%***
Average person along route: urban	**A**	2.1E-08	9.7E-09	9.7E-09	9.7E-09	9.7E-09	**A**	1.3E-12	5.8E-13	5.8E-13	5.8E-13	5.8E-13
	B	2.6E-09	2.6E-09	N/A	6.4E-08	3.1E-09	**B**	1.6E-13	1.6E-13	N/A	3.9E-12	1.9E-13
	A + B	2.4E-08	1.2E-08	9.7E-09	7.4E-08	1.3E-08	**A + B**	1.5E-12	7.4E-13	5.8E-13	4.5E-12	7.7E-13
	A+B % U.S. Annual Background	***7E-07%***	***3E-07%***	***3E-07%***	***2E-06%***	***4E-07%***	***A+B % 2010 Estimated U.S. Cancer Fatalities***	***3E-16%***	***1E-16%***	***1E-16%***	***8E-16%***	***1E-16%***
Average resident near truck stop: rural or suburban	**A**	3.9E-03	1.8E-03	1.8E-03	1.8E-03	1.8E-03	**A**	2.3E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07
	B	4.8E-04	4.8E-04	*N/A*	1.2E-02	5.8E-04	***B***	2.9E-08	2.9E-08	N/A	7.2E-07	3.5E-08
	A+B	4.4E-03	2.3E-03	1.8E-03	1.4E-02	2.4E-03	***A+B***	2.6E-07	1.4E-07	1.1E-07	8.3E-07	1.5E-07
	A+B % U.S. Annual Background	***1.2E-01%***	***6.3E-02%***	***5.0E-02%***	***3.8E-01%***	***6.6E-02%***	***A+B % 2010 Estimated U.S. Cancer Fatalities***	***5E-11%***	***2E-11%***	***2E-11%***	***1E-10%***	***3.E-11%***

[a] Average annual U.S. background dose = 3.6 mSv/year (Shleien et al., 1998).

[b] Based on 2010 total estimated U.S. cancer fatalities of 569,495 (American Cancer Society, 2010).

supported by the negligible LCFs associated with these doses, which range from about 1 x 10^{-16} to 5 x 10^{-11} percent of the total estimated fatal cancer fatalities in the United States in 2010.

A.3.2.2 Impacts on Populations

This section discusses potential radiological impacts, in terms of population doses, from routine spent IER shipments (full casks) on populations. Potential impacts are estimated for populations residing along transportation routes (from moving trucks) and near truck stops (from stationary trucks). For the six alternatives considered in this evaluation, the transportation routes would be between NPPs and waste processing facilities (for blending or volume reduction), between NPPs and LLRW disposal facilities, and between waste processing facilities and LLRW disposal facilities.

The calculation of population dose is based on the concept of "collective dose", which is defined as a radiation dose to a population (expressed in units of person-mSv) calculated by integrating the average radiation dose over the area occupied by the population. For example, if an average person receives a dose of 1.2 x 10^{-9} mSv from one moving truck of spent IERs and there are 10,000 people in the population along the transportation route of that truck, the collective dose to that population from one shipment is 1.2 x 10^{-5} person-mSv (1.2 x 10^{-9} mSv x 10,000 persons = 1.2 x 10^{-5} person-mSv).

The RADTRAN calculation of collective dose requires the identification of specific transportation origins and destinations, and estimates of the populations along the transportation routes between these origins and destinations. For this analysis, a number of "representative" origins and destinations have been identified for use in the modeling. These were selected to be representative of origins of untreated or treated (processed) spent IERs (i.e., NPPs or waste processing facility locations, respectively) and destinations for spent IER processing or disposal (i.e., waste processing facilities or disposal facilities, respectively). The representative origins and destinations selected, although generally based on actual, existing facility locations, are used in this evaluation for illustrative purposes only for calculating potential radiological impacts on populations. They are not meant to designate actual spent IER shipment origins and destinations for the six alternatives because actual routes cannot be identified for generic, non-location-specific alternatives such as those considered in this evaluation.

TRAGIS (TRAnsportation Geographic Information System), the routing code maintained by Oak Ridge National Laboratory (Johnson and Michelhaugh, 2003), is typically used to provide transportation route parameters for use in RADTRAN. However, for this evaluation, the choice of representative origins and destinations and corresponding transportation routes between them was severely constrained because TRAGIS is shut down and unavailable for an undetermined time period (Johnson, 2011). TRAGIS, when available, provides the most recent census data of population densities along routes, a listing of every road and every intersection by highway route number, and the rural, suburban, and urban fractions of the total routes through each state.

Since TRAGIS was not available, the representative transportation origins and destinations and corresponding transportation routing data were constructed from, and limited by, the availability of relevant information on transportation routes in the library of TRAGIS routings maintained by SNL. Within these constraints, the following transportation origins and destinations were selected to allow for the analysis of potential radiological impacts to populations along a range of transportation routes spanning the U.S.:

- As the origins of untreated spent IERs in all six alternatives, actual existing, operating NPP locations were used, including the following four NPPs locations geographically spanning the U.S.:
    - Northeastern U.S. - Indian Point Energy Center (Indian Point) in New York State (NY)
    - Midwestern U.S. - Dresden Generating Station (Dresden) in Illinois (IL)
    - Western/Southwestern U.S. - Palo Verde Nuclear Generating Station (Palo Verde) in Arizona (AZ)
    - Southeastern U.S. - Alvin W. Vogtle Electric Generating Plant (Vogtle) in Georgia (GA).
- For the spent IER central processing (blending or volume reduction) facility in Alternatives 1A, 1B, 4A, and 4B, a location in Tennessee (TN) was selected. This is because Tennessee is a somewhat centralized location in relation to U.S. NPPs, which are located mostly east of the Mississippi River, and because the SNL library of TRAGIS routings includes data for a location in Oak Ridge, Tennessee. This central processing facility location would be the destination for untreated spent IERs to be processed and the origin of processed resins destined for disposal (in alternatives 1A, 1B, and 4B) or long-term storage (in Alternative 4A).
- For the LLRW disposal facility, the existing disposal site location selected for purposes of this evaluation is near Andrews, Texas (TX).

A.3.2.3 Potential Impacts from Routine Transportation

In the subsections that follow, potential radiological impacts on populations from routine transportation are separately estimated and discussed for moving trucks and for trucks at rest and refueling stops.

A.3.2.3.1 Impacts from Moving Trucks

This section discusses the radiological impacts to populations, in terms of collective doses, from routine, incident-free movement of spent IER shipments along transportation routes defined by the origins and destinations identified above. The collective dose from a spent IER shipment (full cask) for each representative transportation route is the sum of the collective doses for the rural, suburban, and urban route segments in all of the states traversed on the route. This summed result is then multiplied by the number of spent IER shipments (full casks) per alternative to obtain the total collective doses for each of the six alternatives.

The area occupied by a receptor population, over which the collective dose is calculated using RADTRAN for each route segment, is a band 800 m (0.5 mile) wide on both sides of the highway multiplied by the length of the route segment. The receptor population in each route segment is the product of this area and the average population density obtained from SNL's library of TRAGIS routings for the particular route segment. Results for rural, suburban, and urban route segments are combined for each route. The rural, suburban, and urban route lengths, average population densities, and average individual doses (from Table A-7) are multiplied appropriately to give the rural, suburban, and urban collective dose for each route. Table A-9 shows the rural, suburban, and urban route lengths, and average population densities for each representative origin-destination combination (or transportation route) considered in this analysis, as obtained from SNL's library of TRAGIS routings.

Using the approach described above with the representative transportation route data in Table A-9 and the average individual doses from Table A-7, the collective (population) doses to populations for one routine shipment of spent IERs (full casks) for each shipping cask type are estimated for each of the representative origin–destination combinations. The results are shown in Table A-10.

Total annual collective (population) doses for all shipments of spent IERs for each alternative, for each representative transportation route, are then calculated as follows:

1. Half the total annual number of Type A and of Type B cask shipments (from Table A-4) for each alternative (i.e., full casks) is multiplied by the collective dose for one routine shipment of spent IERs for each cask type for each route (from Table A-10). This gives the annual collective dose for each route by cask type for each alternative.

2. The results for the two cask types from step 1 above are then added to give the total collective dose for all of the route segments of each alternative. Using Alternative 1A as an example, these collective doses were added for the transportation routes from the NPPs to the waste processing facility and from the waste processing facility to the waste disposal facility.

Table A-11 presents the results of the collective dose calculations using the above steps, and shows the collective doses as percentages of U.S. average annual background doses. In addition, Table A-11 shows the corresponding LCFs calculated as discussed earlier, and compares them, as a percentage, to the American Cancer Society 2010 total estimated U.S. cancer fatalities data.

As Table A-11 shows, the percentages of U.S. annual average background of the estimated total annual collective doses for all six alternatives are all very low and of similar magnitude, ranging from 6×10^{-6} to 7×10^{-5} percent. Thus, since the total collective doses from annual routine shipments of spent IERs in each alternative are all considerably less than the average annual background dose that populations receive, the resulting radiological impacts to populations would be SMALL. Correspondingly, the percentages of 2010 estimated cancer fatalities that the LCF risks shown in Table A-11 are also all very low (the highest being about 1 x 10^{-8} percent), similarly representative of SMALL impacts.

Table A-9 Rural, Suburban, and Urban Route Lengths and Population Densities for the Representative Transportation Routes

DESTINATIONS[a]	STATES ON THE ROUTE	RURAL		SUBURBAN		URBAN	
		Route Length (km)[b]	Population Density (people/ km^2)[c]	Route Length (km)	Population Density (people/ km^2)	Route Length (km)	Population Density (people/ km^2)
Indian Point (NY) NPP to Waste Processing and Disposal Facilities							
Processing (TN)	MD	5.7	18.8	12.3	380	1.4	1765
	NJ	40.2	19.7	67.6	478.5	14.2	2338
	NY	11.7	13.2	28.1	583.4	16.4	2569
	PA	134.5	22.6	120.4	335.4	11	2257
	TN	110.8	21.9	109.6	314.5	6.1	1849
	VA	282	18	230	280	9.7	2192
	WV	12.6	29.5	28.8	342.6	0.7	1979
Disposal (TX)	AR	317.4	14.4	130	273.4	8.4	2060
	MD	5.7	18.8	12.3	380	1.4	1765
	NJ	40.2	19.7	67.6	478.5	14.2	2338
	NY	11.7	13.2	28.1	583.4	16.4	2569
	OK	428.4	11.9	98.2	311.5	8.4	2339
	PA	134.5	22.6	120.4	335.4	11	2257
	TN	496.4	18.1	241.4	314.3	31.3	2172
	TX	220	5.2	18.8	400	7.2	2148
	VA	282	18	230	280	9.7	2192
	WV	12.6	29.5	28.8	342.6	0.7	1979
Dresden (IL) NPP to Waste Processing and Disposal Facilities							
Processing (TN)	IL	27.7	24.6	133.9	482.4	29	2456
	IN	249.1	16.9	139.5	313.7	16.9	2285
	KY	171.8	22.5	138.9	282.1	11.5	2145
	OH	10.8	18	9.3	337.5	1.1	19.0
	TN	71.3	15.7	57.4	384.9	7.1	1908
Disposal (TX)	IL	308.9	16.1	203.1	289.2	10.3	2261
	MO	291.5	19.8	158.1	324	8.7	2077
	OK	640.3	4.3	12.6	283	1.1	1765
	TX	341.3	4.8	18.9	399.1	7.2	2148

Table A-9 Rural, Suburban, and Urban Route Lengths and Population Densities for the Representative Transportation Routes (Cont.)

DESTINATIONS[a]	STATES ON THE ROUTE	RURAL		SUBURBAN		URBAN	
		Route Length (km)[b]	Population Density (people/ km^2)[c]	Route Length (km)	Population Density (people/ km^2)	Route Length (km)	Population Density (people/ km^2)
Palo Verde (AZ) NPP to Waste Processing and Disposal Facilities							
Processing (TN)	AR	317.2	14.4	130	276.5	8.5	2052
	AZ	533.2	7	37.9	369.9	3.6	2312
	NM	519.7	7.7	63.5	308.9	13.8	2387
	OK	425.7	11.9	100	308.8	4.3	2098
	TN	12.1	17.6	11.7	430	5.1	2521
	TX	256.9	4.8	18.9	399.1	7.2	2148
Disposal (TX)	AZ	533.2	7	37.9	369.9	3.6	2312
	NM	220	7.7	18.9	308.9	6.8	2387
	TX	36.9	4.8	0	0	0	0
Vogtle (GA) NPP to Waste Processing and Disposal Facilities							
Processing (TN)	GA	189.3	18	145.3	359.7	24.2	2210
	SC	14.4	16	6	295.3	0.4	2045
	TN	12.1	17.6	11.7	430	5.1	2521
Disposal (TX)	AL	225.2	17.5	111.3	278	6.3	2034
	GA	274.6	18	145.3	359.7	24.2	2210
	LA	206.8	12.5	96.4	282.2	5.2	1950
	MS	172.8	16.5	71.2	306.4	3.9	2010
	NM	196.8	4.2	6.7	412.6	1.0	2044
	SC	14.4	16	8	295.3	1.4	2045
	TX	804.6	11.6	211.8	322.2	23.7	2248
Waste Processing Facility (TN) to Waste Disposal Facility (TX)							
Disposal (TX)	AR	317.4	14.4	130	273.4	8.4	2060
	OK	428.4	11.9	98.2	311.5	8.4	2339
	TN	496.4	18.1	281.4	314.3	31.3	2172
	TX	220.1	5.2	18.8	400	7.2	2148

[a] Since TRAGIS was not available, the representative transportation origins and destinations and corresponding transportation routing data were constructed from, and limited by, the availability of relevant information on transportation routes in the library of TRAGIS routings maintained by SNL (see text).

[b] km = kilometers.

[c] km^2 = square kilometers.

Table A-10 Collective (Population) Doses by Cask Type for One Routine Shipment of Spent IERs for Representative Transportation Routes (Moving Trucks)

TRANSPORTATION ROUTES		COLLECTIVE DOSE (PERSON-mSv)			
Origin	**Destination**	**Rural**	**Suburban**	**Urban**	**Total**
Type A Cask (CNS 14-215)					
Indian Point, NY	Processing (TN)	1.5E-05	2.5E-04	2.9E-06	2.6E-04
	Disposal (TX)	3.6E-05	3.0E-04	3.9E-07	3.4E-04
Dresden, IL	Processing (TN)	1.2E-05	2.1E-04	3.1E-06	2.3E-04
	Disposal (TX)	1.8E-05	1.5E-04	1.2E-06	1.7E-04
Palo Verde, AZ	Processing (TN)	2.3E-05	1.4E-04	6.3E-07	1.6E-04
	Disposal (TX)	6.1E-06	2.6E-05	5.0E-07	3.3E-05
Vogtle, GA	Processing (TN)	4.7E-06	6.6E-05	1.4E-06	7.3E-05
	Disposal (TX)	3.0E-05	2.5E-04	2.9E-06	2.8E-04
Processing (TN)	Disposal (TX)	2.4E-05	2.0E-04	2.5E-06	2.2E-04
Type B Cask (CNS 8-120B)					
Indian Point, NY	Processing (TN)	1.4E-05	2.4E-04	2.9E-06	2.5E-04
	Disposal (TX)	3.6E-05	3.0E-04	5.2E-06	3.4E-04
Dresden, IL	Processing (TN)	1.2E-05	2.1E-04	3.2E-06	2.3E-04
	Disposal (TX)	1.9E-05	1.5E-04	1.2E-06	1.7E-04
Palo Verde, AZ	Processing (TN)	2.3E-05	1.4E-04	2.0E-06	1.6E-04
	Disposal (TX)	6.1E-06	2.7E-05	5.0E-07	3.3E-05
Vogtle, GA	Processing (TN)	5.5E-07	9.1E-06	2.9E-07	9.9E-06
	Disposal (TX)	2.6E-05	2.1E-04	3.0E-06	2.4E-04
Processing (TN)	Disposal (TX)	1.9E-05	1.6E-04	2.2E-06	1.8E-04

A.3.2.3.2 Impacts from Trucks at Rest and Refueling Stops

This section discusses collective radiation doses and associated potential radiological impacts to receptors from tractor-trailer trucks carrying spent IERs (full casks) that have stopped at truck stops for rest and refueling. External radiation from the shipping casks on these trucks would result in a collective dose to members of the public who live near the truck stops.

Tractor-trailer trucks tend to stop for rest and refueling when the two fuel tanks that they carry are approximately half empty (DOE, 2002; Appendix J). The average fuel mileage for a loaded 18-wheel tractor-trailer is 6.5 miles/gallon (mi/gal) and these trucks generally have two 80-gal fuel tanks. Thus, these trucks would stop to refuel about every 520 miles, on average (80 gal × 6.5 mi/gal = 520 miles). Truck crewmembers try to combine activities at a stop; typically, one

Table A-11 Annual Radiological Impacts on Populations from Routine Transportation of All Spent IER Shipments for Each Alternative by Representative Transportation Route (Moving Trucks)

ORIGIN NPP LOCATION	MEASURES OF POTENTIAL RADIOLOGICAL IMPACTS	ANNUAL COLLECTIVE DOSE AND LCF BY ALTERNATIVE[a]				
		1A and 1B[b]	2 and 3 (after Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B[b]
Indian Point, NY	Annual Collective Dose (Person-mSv)	0.25	0.18	0.14	0.94	0.17
	Annual Collective Dose as % U.S. Annual Background[c]	2E-05%	7E-06%	6E-06%	4E-05%	7E-06%
	Collective LCF	1.5E-05	1.1E-05	8.5E-06	5.7E-05	1.0E-05
	LCF as % 2010 Estimated U.S. Cancer Fatalities[d]	3E-09%	2E-09%	1E-09%	1E-08%	2E-09%
Dresden, IL	Annual Collective Dose (Person-mSv)	0.23	0.089	0.070	0.46	0.10
	Annual Collective Dose as % U.S. Annual Background	9E-06%	1E-05%	1E-05%	7E-05%	7E-05%
	Collective LCF	1.4E-05	5.3E-06	4.2E-06	2.8E-05	6.0E-06
	LCF as % 2010 Estimated U.S. Cancer Fatalities	2E-09%	9E-10%	7E-10%	5E-09%	1E-09%
Palo Verde, AZ	Annual Collective Dose (Person-mSv)	0.19	0.017	0.014	0.091	0.036
	Annual Collective Dose as % of U.S. Annual Background	4E-05%	1E-05%	1E-05%	5E-05%	2E-05%
	Collective LCF	1.2E-05	1.0E-06	8.3E-07	5.5E-06	2.2E-06
	LCF as % 2010 Estimated U.S. Cancer Fatalities	2E-09%	2E-10%	1E-10%	1E-09%	4E-10%
Vogtle, GA	Annual Collective Dose (Person-mSv)	0.14	0.15	0.12	0.69	0.12
	Annual Collective Dose as % of U.S. Annual Background	1E-05%	9E-05%	7E-05%	4E-05%	7E-05%
	Collective LCF	8.4E-06	8.8E-06	7.1E-06	4.1E-05	7.5E-06
	LCF as % 2010 Estimated U.S. Cancer Fatalities	1E-09%	2E-09%	1E-09%	7E-09%	1E-09%

[a] Because of the uncertainties inherent in this type of analysis (Weiner et al, 2009), percentages are reported to one significant figure and radiation doses and LCFs to two significant figures.

[b] The collective doses for Alternatives 1A and 1B and Alternatives 4A and 4B are the sum of the collective doses from the NPP to the processing facility and from the processing facility to disposal.

[c] The annual collective dose as % of U.S. average annual background dose was calculated by dividing the annual collective dose by the total number of persons exposed along the shipment route and then dividing by the annual background dose of 3.6 mSv/year (Shleien et al., 1998), and then multiplying by 100 to obtain a percentage.

[d] LCF as % of 2010 total estimated U.S. cancer fatalities was calculated by dividing the LCF by the U.S. estimated number of annual cancer fatalities for 2010, which was 569,495 (American Cancer Society, 2010) and then multiplying by 100 to obtain a percentage.

crew member fills the tank while the other uses the facilities, buys food, etc. (Griego et al., 1996). As shown in Table A-6, the average time spent at a truck stop is about 0.33 hour.

Truck stops that would serve the 18-wheel tractor-trailer trucks that carry Type A or Type B casks containing spent IERs would mostly be located in rural or suburban areas near freeway access ramps. Each truck stop is surrounded by a different resident population. This analysis conservatively assumes that the resident population at each truck stop would be exposed to all of the shipments in each alternative. Tables A-12 through A-14 show the intermediate and final results of the analysis to determine impacts to populations near truck rest and refueling stops. Table A-12 provides estimates of the average numbers of truck stops on each of the representative transportation routes identified in Section A.3.2.3.1. The number of stops is determined by dividing the total route length by 520, the approximate number of miles between refueling stops (see above). Table A-13 provides the average rural and suburban population densities (derived from information in Table A-9; see Table A-13, footnote a). Table A-13 also shows the populations near truck stops for each representative transportation route, which are estimated by multiplying the population densities by the annular area between 30 and 800 meters around the truck stop—i.e., 2.0 square kilometers (km^2) (0.77 square mile (mi^2)).[12]

As shown in Table A-7, the average individual external dose to a resident near a rural or suburban truck stop from either cask type is about 4.3×10^{-6} mSv. Multiplying this average individual external dose by the rural or suburban population numbers in Table A-13 yields the collective dose for one routine spent IER shipment for each population zone (rural or suburban) and representative origin-destination combination. Then, multiplying this collective dose per shipment by the number of spent IER shipments (full casks) yields the collective dose for each alternative. These results are shown for rural and suburban truck stops in Table A-14.

As shown in Table A-14, the estimated total annual collective doses are all a small fraction of background, ranging from 0.03 to 0.2 percent of background at rural truck stops and 1.2 to 3.6 percent at suburban stops. Thus, since the total collective doses from annual routine shipments of spent IERs in each alternative are all lower than the average annual background dose that populations receive, the resulting radiological impacts to populations would be SMALL. Any differences between the collective doses to residents near rural and suburban truck stops depend only on the difference in population (with the populations near suburban trucks stops typically being higher). The radiation source and its strength are the same in both cases. Further, the LCFs as percentages of 2010 U.S. total estimated cancer fatalities shown in Table A-14 are also all negligible, the highest being about 4×10^{-8} percent, representing similarly SMALL impacts. Note that in actual practice, impacts would be lower than estimated because not all trucks carrying spent IERs would stop at the same rest stops and not all residents would be at the same locations for an entire year.

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[12] RADTRAN assumes that potentially affected populations near truck stops reside no closer than a minimum radius of 30 m (0.03 km), and no farther than a maximum radius of 800 m (0.8 km), from the stop (see Table A-6). Thus, the area (in km^2) in which these populations reside can be calculated as follows: Area = $\pi \times [(0.8\ km)^2 - (0.03\ km)^2] = 2.0\ km^2$.

Table A-12 Average Number of Truck Stops for Each Representative Transportation Route (Trucks Carrying Full Casks of Spent IERs)

ORIGIN	DESTINATION	ONE-WAY ROUTE MILES[a]	TRUCK REFUELING STOPS[b]
Indian Point, NY	Processing (TN)	779	1
	Processing (TN) + Disposal (TX)	2283	4
	Direct Disposal (TX)	1911	4
Dresden, IL	Processing(TN)	668	1
	Processing (TN) + Disposal (TX)	2171	2
	Direct Disposal (TX)	1244	5
Palo Verde, AZ	Processing (TN)	1534	3
	Processing (TN) + Disposal (TX)	3037	6
	Direct Disposal (TX)	533	1
Vogtle, GA	Processing (TN)	255	1[c]
	Processing (TN) + Disposal (TX)	1758	4
	Direct Disposal (TX)	1622	3
Processing (TN)	Disposal (TX)	1503	3

[a] Summation of rural, suburban, and urban route distances from Table A-9.

[b] Calculated by dividing the one-way route miles by the approximate number of miles between refueling stops (i.e., 520 miles, as calculated in the text above) and rounded.

[c] Actually, 255/520 = 0.5, so the truck might not have to stop at all. Listing 1 stop is conservative.

In comparing the collective doses as percent of background in Table A-11 (for moving trucks) with those in Table A-14 (for stopped trucks), it is evident that the percentages in the former case are notably lower than those in the latter. This is because the collective dose percent of background dose is directly related to the time during which a population is exposed to the spent IER shipments. RADTRAN assumes that each resident near a truck stop is exposed to the radiation from the shipping cask on a stopped (stationary) truck for 0.33 hour (about 20 minutes) (see above and Table A-6). However, a resident along a transportation route is exposed to radiation from a moving truck for only a few tenths of a second at most (based on 108 kph truck speed (from Table A-5) = 30 m/sec = 3 m/0.1 second). This difference is also reflected in Table A-7: where the dose to the average individual near a truck stop is larger than the dose to the average individual along the route. Nevertheless, as indicated above and in Section A.3.2.3.1, radiological impacts due to radiation exposures to populations from stationary trucks near truck stops and from moving trucks along transportation routes, respectively, would both be SMALL.

Table A-13 Average Rural and Suburban Population Densities and Populations near Truck Stops for Each Representative Transportation Route

ORIGIN	DESTINATION	AVERAGE POPULATION DENSITY (People/km^2)[a,b]		POPULATION[a,c]	
		RURAL	SUBURBAN	RURAL	SUBURBAN
Indian Point, NY	Processing (TN)	21	388	41	778
	Disposal (TX)	17	370	34	743
Dresden, IL	Processing (TN)	20	360	39	723
	Disposal (TX)	11	324	23	650
Palo Verde, AZ	Processing (TN)	11	349	21	700
	Disposal (TX)	6	385	12	772
Vogtle, GA	Processing (TN)	17	363	28	647
	Disposal (TX)	14	322	34	728
Processing (TN)	Disposal (TX)	12	270	35	542

[a] All numbers in these columns are rounded numbers from calculations.

[b] The data in the two columns below represent the averages of the state rural and suburban population densities listed in Table A-9 for each origin-destination combination.

[c] This would be the resident population in an annulus defined by radii of between 30 to 800 meters from the stopped truck (see text).

A.3.3 Non-radiological and Radiological Impacts of Transportation Accidents

Trucks carrying spent IERs or empty casks are as likely to be involved in traffic accidents as any other similar heavy trucks. Potential non-radiological and radiological impacts of transportation accidents as a result of traffic collisions involving trucks carrying spent IER shipments are evaluated in this section. Section A.3.3.1 assesses potential non-radiological impacts of transportation accidents, measured in terms of the number of traffic accidents and the number of traffic accident fatalities from the transport of both full and empty casks. Section A.3.3.2 evaluates the radiological impacts of traffic accidents involving trucks carrying full shipping casks of spent IERs, under scenarios in which radioactive materials are and are not released.

A.3.3.1 Non-Radiological Impacts of Transportation Accidents

In this evaluation, non-radiological impacts of transportation accidents are assessed in terms of the number of traffic accidents and the number of traffic accident fatalities from implementation of each alternative. These potential non-radiological impacts are estimated using tractor-trailer truck traffic accident and accident fatality rate information coupled with the total distances driven under each alternative with full and empty casks.

Table A-14 Annual Radiological Impacts to Populations near Truck Stops from Routine Spent IER Shipments for Each Alternative

ORIGIN NPP LOCATION	TOTAL ANNUAL COLLECTIVE DOSE (mSv) FROM SPENT IER SHIPMENTS TO RESIDENTS NEAR A TRUCK STOP, BY ALTERNATIVE[a, b]						TOTAL ANNUAL LCF FROM SPENT IER SHIPMENTS TO RESIDENTS NEAR A TRUCK STOP, BY ALTERNATIVE[a]					
		1A and 1B[c]	2 and 3 (After Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B[c]		1A and 1B[c]	2 and 3 (After Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B[c]
Indian Point, NY	**Rural Stop**	0.16	0.078	0.062	0.41	0.084	**Rural Stop**	9.4E-06	4.7E-06	3.7E-06	2.4E-05	5.0E-06
	% U.S. Annual Background[d]	0.1%	0.1%	0.1%	0.3%	0.1%	***% U.S. 2010 Estimated Cancer Fatalities[e]***	2E-09%	8E-10%	7E-10%	4E-09%	9E-10%
	Suburban Stop	3.6	1.3	1.3	8.8	1.8	**Suburban Stop**	2.2E-04	7.8E-05	8.0E-05	5.3E-04	0.00011
	% U.S. Annual Background	0.1%	0.1%	0.1%	0.3%	0.1%	***% U.S. 2010 Estimated Cancer Fatalities***	4E-08%	1E-08%	1E-08%	9E-08%	2E-08%
Dresden, IL	**Rural Stop**	0.15	0.051	0.041	0.27	0.062	**Rural Stop**	9.2E-06	3.1E-06	2.4E-06	1.6E-05	3.7E-06
	% U.S. Annual Background	0.2%	0.1%	0.1%	0.3%	0.1%	***% U.S. 2010 Estimated Cancer Fatalities***	2E-09%	5E-10%	4E-10%	3E-09%	7E-10%
	Suburban Stop	3.5	1.5	1.2	8.6	1.6	**Suburban Stop**	2.1E-04	9.1E-05	7.0E-05	5.2E-04	9.5E-05
	% U.S. Annual Background	0.2%	0.1%	0.1%	0.4%	0.1%	***% U.S. 2010 Estimated Cancer Fatalities***	4E-08%	2E-08%	1E-08%	9E-08%	2E-08%
Palo Verde, AZ	**Rural Stop**	0.11	0.027	0.021	0.14	0.034	**Rural Stop**	6.7E-06	1.6E-06	1.3E-06	8.4E-06	2.0E-06
	% U.S. Annual Background	0.2%	0.04%	0.03%	0.2%	0.04%	***% U.S. 2010 Estimated Cancer Fatalities***	1E-09%	3E-10%	3E-10%	2E-09%	4E-10%
	Suburban Stop	3.4	1.7	1.4	7.9	1.8	**Suburban Stop**	2.1E-04	1.0E-04	8.3E-05	4.7E-04	1.1E-04
	% U.S. Annual Background	0.1%	0.1%	0.1%	0.3%	0.1%	***% U.S. 2010 Estimated Cancer Fatalities***	4E-08%	2E-08%	2E-08%	8E-08%	2E-08%
Vogtle, GA	**Rural Stop**	0.14	0.063	0.050	0.33	0.065	**Rural Stop**	8.4E-06	3.8E-06	3.0E-06	2.0E-05	8.4E-06
	% U.S. Annual Background	0.1%	0.1%	0.1%	0.3%	0.1%	***% U.S. 2010 Estimated Cancer Fatalities***	2E-09%	7E-10%	5E-10%	3E-09%	7E-10%
	Suburban Stop	3.5	1.5	1.2	8.9	1.5	**Suburban Stop**	2.1E-04	9.2E-05	7.0E-05	5.5E-04	9.3E-05
	% U.S. Annual Background	0.2%	0.1%	0.1%	0.4%	0.1%	***% U.S. 2010 Estimated Cancer Fatalities***	4E-08%	2E-08%	1E-08%	9E-09%	2E-08%

[a] Because of the uncertainties inherent in this type of analysis (Weiner, et al, 2009), percentages are reported to one significant figure and radiation doses and LCFs to two significant figures.

[b] The annual collective dose for a rural or suburban truck stop is equal to the average individual external dose to a resident near the truck stop (from Table A-7) multiplied by the population and half of the total annual shipments of Type A and Type B casks (from Table A-4) for each shipment route.

[c] The collective doses for Alternatives 1A and 1B and Alternatives 4A and 4B are the sum of the collective dose s from the NPP to the waste processing facility and from the waste processing facility to disposal.

[d] The annual collective dose as a percentage of annual background was calculated by dividing the annual collective dose by the rural population along the shipment route and then dividing by the annual background dose of 3.6 mSv/year (Shleien et al., 1998), and multiplying by 100 to obtain a percentage.

[e] The LCF risk as % of 2010 U.S. estimated cancer fatalities was calculated by dividing the LCF risk by U.S. estimated annual cancer fatalities for 2010, which was 569.495 (American Cancer Society, 2010) and multiplying by 100 to obtain a percentage.

Tractor-trailer truck accident rates by state are first estimated. Table A-15 shows these accident rates as the number of truck accidents per kilometer driven (tractor-trailer-truck-km), for the contiguous 48 states and the District of Columbia (information is not provided in Table A-15 for Alaska and Hawaii as there are no NPPs in those states and no spent IERs would be transported through those states). Since the USDOT does not specifically provide this information, the numbers of accidents per truck-km in Table A-15 are calculated using other USDOT traffic fatality data from the year 2009, the most recent data available.

Table A-15 Estimated Tractor-Trailer Truck Accident Rates in the Contiguous States and District of Columbia

STATE	ACCIDENTS PER TRACTOR-TRAILER TRUCK-KM	STATE	ACCIDENTS PER TRACTOR-TRAILER TRUCK-KM
Alabama	4.95E-07	**Nebraska**	6.70E-07
Arizona	4.05E-07	**Nevada**	3.40E-07
Arkansas	8.24E-07	**New Hampshire**	1.85E-07
California	2.76E-07	**New Jersey**	2.87E-07
Colorado	2.79E-07	**New Mexico**	4.73E-07
Connecticut	1.61E-07	**New York**	2.68E-07
Delaware	2.61E-07	**North Dakota**	3.78E-07
District of Columbia	9.86E-08	**North Carolina**	1.30E-06
Florida	3.17E-07	**Ohio**	3.19E-07
Georgia	4.11E-07	**Oklahoma**	6.28E-07
Idaho	4.56E-07	**Oregon**	3.08E-07
Illinois	2.78E-07	**Pennsylvania**	4.23E-07
Indiana	4.56E-07	**Rhode Island**	2.29E-07
Iowa	6.86E-07	**South Carolina**	5.62E-07
Kansas	6.19E-07	**South Dakota**	5.08E-07
Kentucky	7.44E-07	**Tennessee**	4.29E-07
Louisiana	5.99E-07	**Texas**	4.30E-07
Maine	4.44E-07	**Utah**	3.17E-07
Maryland	2.97E-07	**Vermont**	2.73E-07
Massachusetts	1.33E-07	**Virginia**	3.32E-07
Michigan	2.21E-07	**Washington**	1.94E-07
Minnesota	3.03E-07	**West Virginia**	5.28E-07
Mississippi	5.04E-07	**Wisconsin**	2.98E-07
Missouri	4.22E-07	**Wyoming**	5.60E-07
Montana	7.02E-07		

Source: Derived from USDOT 2009 state and national transportation statistics data as discussed in the text.

Table 2-1 in the USDOT's "State Transportation Statistics 2010" (USDOT, 2010) provides, for each state, the vehicle fatalities per 100,000 people, the number of people driving vehicles in the state, and the vehicle-miles traveled in that state. From that information, vehicle fatalities per vehicle mile are calculated as follows:

> *State vehicle fatalities per vehicle-mile =*
> [(vehicle fatalities/100,000 people) x (number of people driving)] ÷ (vehicle-miles driven)

Table 2-3 of the same USDOT (2010) publication gives the fraction of vehicle fatalities for each state that are tractor-trailer truck fatalities. From that information, tractor-trailer truck fatalities per tractor trailer-truck-mile are calculated as follows:

> *State tractor-trailer truck fatalities per tractor-trailer-truck-mile =*
> (vehicle fatalities per vehicle-mile) x (fraction of fatalities for tractor-trailer trucks)

Table 2-1 in the USDOT's "National Transportation Statistics 2011" (USDOT, 2011) gives 2009 total U.S. tractor-trailer truck fatalities and Table 2-3 in that publication gives 2009 total U.S. tractor-trailer truck accidents. Assuming that traffic fatalities in each state are proportional to national traffic accidents, then the tractor-trailer truck accidents per tractor-trailer-truck-mile for each state are calculated as follows:

> *State tractor-trailer truck accidents per tractor-trailer truck-mile =*
> (tractor-trailer truck fatalities/tractor-trailer-truck-mile) x (tractor-trailer accidents ÷ tractor-trailer fatalities)

Tractor-trailer truck accidents per tractor-trailer-truck-mile were then converted to tractor-trailer truck accidents per tractor-trailer-truck-km by multiplying by 0.62137, to obtain the figures shown in Table A-15.

Projected annual numbers of spent IER tractor-trailer truck traffic accidents and traffic accident-related fatalities (full and empty casks) were then calculated for each alternative for each representative transportation origin-destination combination identified in Section A.3.2.3. The results are shown in Table A-16. In this table, the estimated annual number of spent IER truck accidents are compared with annual U.S. tractor-trailer truck accidents as percentages (based on 367,920 annual tractor-trailer truck accidents in 2009 (USDOT, 2011; Table 2-3)). In addition, estimated annual fatalities involving spent IER tractor-trailer trucks are similarly compared with annual U.S. fatalities involving all tractor-trailer trucks (based on 503 annual tractor trailer accident fatalities in 2009 (USDOT, 2011; Table 2-1)).

The information in Table A-16 is based on traffic accident and fatality rates for tractor-trailer trucks, the distance driven for each route (from the one-way route kilometers from Table A-9, and the annual number of shipments by alternative (including full and empty casks), from Table A-2). A sample calculation is presented below, showing how the results in Table A-16 were derived. This sample calculation is for Alternative 3 (Years 1-20) and the transportation route originating from Indian Point, NY. The sample calculation computes the total potential accidents along the route by multiplying the following: the total kilometers traveled per state (rural + suburban + urban), the state-specific tractor-trailer truck accident rate for the distance traveled in that state, and the annual number of shipments traversing that route.

Table A-16 Estimated Annual Tractor-Trailer Accidents and Fatalities for Representative Transportation Routes to Disposal by Alternative (Full and Empty Casks)

ORIGIN NPP LOCATION	MEASURES OF POTENTIAL NON-RADIOLOGICAL IMPACTS	ANNUAL SPENT IER TRUCK ACCIDENTS AND FATALITIES BY ALTERNATIVE				
		1A and 1B[a]	2 and 3 (After Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B[a]
Indian Point, NY	**Annual No. of Spent IER Truck Accidents**	1.6	2	1.3	8	1
	% of Annual U.S. Tractor-Trailer Truck Accidents[b]	0.0004%	0.0004%	0.0003%	0.002%	0.0001%
	Projected Annual Fatalities Involving Spent IER Shipments	0.01	0.01	0.01	0.06	0.01
	% of Annual U.S. Fatalities Involving All Tractor-Trailer Trucks[c]	0.002%	0.002%	0.002%	0.012%	0.002%
Dresden, IL	**Annual No. of Spent IER Truck Accidents**	1.7	1	0.7	4	1
	% of Annual U.S. Tractor-Trailer Truck Accidents	0.0005%	0.0002%	0.0002%	0.001%	0.0001%
	Projected Annual Fatalities Involving Spent IER Shipments	0.01	0.01	0.005	0.03	0.005
	% of Annual U.S. Fatalities Involving All Tractor-Trailer Trucks	0.002%	0.002%	0.001%	0.006%	0.001%
Palo Verde, AZ	**Annual No. of Spent IER Truck Accidents**	2.6	0.4	0.3	2	0.3
	% of Annual U.S. Tractor-Trailer Truck Accidents	0.0007%	0.0001%	0.0001%	0.0005%	0.0.0001%
	Projected Annual Fatalities Involving Spent IER Shipments	0.02	0.002	0.002	0.01	0.002
	% of Annual U.S. Fatalities Involving All Tractor-Trailer Trucks	0.004%	0.0004%	0.0004%	0.002%	0.0005%
Vogtle, GA	**Annual No. of Spent IER Truck Accidents**	1.2	1	0.3	4	1
	% of Annual U.S. Tractor-Trailer Truck Accidents	0.0003%	0.0001%	0.0001%	0.0009%	0.0001%
	Projected Annual Fatalities Involving Spent IER Shipments	0.01	0.01	0.002	0.03	0.005
	% of Annual U.S. Fatalities Involving All Tractor-Trailer Trucks	0.002%	0.002%	0.0004%	0.006%	0.001%

[a] The accidents and fatalities for Alternatives 1A and 1B and Alternatives 4A, and 4B are the sum of the accidents and fatalities from the NPP to the waste processing facility and from the processing facility to disposal.

[b] Based on 367,920 annual tractor-trailer truck accidents in 2009 (USDOT, 2011).

[c] Based on 503 annual U.S. fatalities involving all tractor-trailer trucks in 2009 (USDOT, 2011).

Sample Calculation Showing How Data Presented in Table A-16 Are Derived:

Indian Point, NY, to Disposal, for Alternative 3 (Years 1-20) with 838 Annual Shipments

A. Total Truck Kilometers Traveled (Rural + Suburban + Urban) (from Table A-9):

In AR: 317.4 km + 130 km + 8.4 km = 455.8 km
In MD: 5.7 km + 12.3 km + 1.4 km = 19.4 km
In NJ: 40.2 km + 67.6 km + 14.2 km = 122.0 km
In NY: 11.7 km + 28.1 km + 16.4 km = 56 .2 km
In OK: 428.2 km + 98.2 km + 8.4 km = 535 km
In PA: 134.5 km + 120.4 km + 11 km = 265.9 km
In TN: 496.4 km + 241.4 km + 31.3 km = 769.1 km
In TX: 220 km + 18.8 km + 7.2 km = 246 km
In VA: 282 km + 230 km + 9.7 km = 521.7 km
In WV: 12.6 km + 28.8 km + 0.7 km = 42.1 km

B. State Tractor-Trailer Truck Accident Rates per km (from Table A-15):

AR: 8.24×10^{-7}
MD: 2.97×10^{-7}
TX: 4.30×10^{-7}
NY: 2.68×10^{-7}
OK: 6.28×10^{-7}
PA: 4.23×10^{-7}
TN: 4.29×10^{-7}
TX: 4.30×10^{-7}
VA: 3.32×10^{-7}
WV: 5.28×10^{-7}

C. Annual State Tractor-Trailer Truck Accidents: A x B X 838 shipments/year

No. of accidents in AR: 0.315 accident/year
No. of accidents in MD: 0.00483 accident/year
No. of accidents in NJ: 0.0293 accident/year
No. of accidents in NY: 0.0126 accident/year
No. of accidents in OK: 0.282 accident/year
No. of accidents in PA: 0.0943 accident/year
No. of accidents in TN: 0.277 accident/year
No. of accidents in TX: 0.0886 accident/year
No. of accidents in VA: 0.145 accident/year
No. of accidents in WV: 0.0197 accident/year

D. Total Potential Annual Accidents from Indian Point, NY to Disposal:

0.315 + 0.00483 + 0.0293 + 0.0126 + 0.282 + 0.0941 + 0.277 + 0.0886 + 0.145 + 0.0197
≈ 1.3 accidents/year

U.S. tractor-trailer truck traffic fatalities in 2009, used in Table A-16, were calculated from national statistics in Tables 2-1 and 2-3 of USDOT (2011), as shown below. 2009 data are the most recent available.

2009 U.S. tractor-trailer truck accidents (from Table 2-3) = 367,920
2009 U.S. tractor-trailer truck fatalities (from Table 2-1) = 503
Fatalities per accident = 503 ÷ 367,920 = 0.00137

As shown in Table A-16, the largest estimated annual number of potential traffic accidents involving spent IER shipments (full and empty casks) is 2.6 accidents for the transportation route originating in Palo Verde, AZ, for Alternatives 1A and 1B. This number of accidents is 0.0007 percent of the annual number of tractor-trailer truck accidents in the U.S. Also from Table A-16, the largest number of potential traffic fatalities is 0.02 per year for the same Palo Verde origin for Alternatives 1A and 1B. This is equivalent to one fatal traffic accident every 50 years, and is 0.004 percent of the total annual U.S. truck fatalities. Thus, the non-radiological impacts represented by the projected numbers of tractor-trailer truck accidents and associated number of traffic accident fatalities would be SMALL.

A.3.3.2 Radiological Impacts of Transportation Accidents

The potential radiological impacts of accidents involving the transport of untreated and treated (processed) spent IERs in Type A and Type B shipping casks (full casks) are evaluated in this section. Two types of transportation accidents are considered involving trucks transporting radioactive materials that could have radiological impacts:

- Accidents in which there is no impact on the cask and, therefore, no release of radioactive material; and
- Accidents in which there is an impact on the cask, and radioactive material could be released.

Sections A.3.3.2.1 and A.3.3.2.2 evaluate the consequences of these two accident scenarios, respectively. The distinction between the two types of accidents is made because more than 91 percent of all accidents involving trucks carrying radioactive material and more than 99 percent of accidents involving Type B casks do not result in any damage to the cargo; therefore, these accidents would not involve a release of radioactive material (NRC, 1977; Table 5-3; Sprung et al., 2000: Chapter 7, pp. 7-73 to 7-76).

A.3.3.2.1 Accidents with No Release of Radioactive Materials

This section evaluates potential radiological impacts to members of the public from transportation accidents in which the spent IER cargo in full Type A or Type B casks on tractor-trailer trucks is not impacted (i.e., no radioactive materials are released from the shipping casks), but in which the tractor-trailers would be disabled and stationary and require assistance. Since no radioactive materials would be released, exposure would be from the external radiation from the casks; and the analysis is conservatively based on the legally-defined maximum external dose rates from the Type A and Type B casks. For each representative route in each of the six alternatives, the consequence of an accident is represented by the collective (population) dose to residents near the location of the accident. The dose to the nearest member of the public, the MEI, is also calculated.

The doses to individuals and populations near the accident sites are calculated using RADTRAN in a similar fashion as individual and collective doses are calculated near routine transportation stops (i.e., truck rest and refueling stops; see Section A.3.2.3.2), except that RADTRAN models the duration of the stop as a result of an accident as 10 hours rather than the 0.33 hour for the routine stop (see Table A-6) and multiplies the resulting dose by the accident probability[13] along the route where the stop occurs. An accident, even a minor accident, would generally require the removal of the cask, either by transferring it by crane to another vehicle or by removing the truck and cask from the accident scene. Considering the size and weight of the full casks (see Table A-1), it could take several hours to deploy appropriate equipment for this purpose at the accident location; and 10 hours is assumed for the RADTRAN assessment.

Additionally, the RADTRAN modeling to calculate collective (population) doses in this evaluation is conducted based on an average population near a suburban truck stop because that is more conservative than modeling for an average population near a rural truck stop (i.e., suburban populations are larger than rural populations). Thus, the accident is assumed to take place on a suburban highway, the distance to the nearest member of the public would be 30 m (98 ft) (from Table A-6), and the affected population would be the population between 30 and 800 meters from the accident (from Table A-6).

Table A-17 presents the RADTRAN-calculated collective doses to residents near the accident and associated collective LCFs for each alternative, for the representative transportation routes identified in Section A.3.2.2. The collective doses are calculated in the following manner:

> *Collective dose (person-mSv) =*
> *[average suburban population (from Table A-13)] x [average individual dose near truck stop for either a Type A or Type B cask (from Table A-7[14])] x [number of full cask shipments (one half of Table A-4 values)] x [accident probability]*

In Table A-17, the calculated collective doses are compared to average annual background dose. In addition, estimated annual fatalities for traffic accidents involving spent IER tractor-trailer trucks (from Table A-16) are included to compare potential cancer fatalities from radiation exposure to spent IER shipments during a traffic accident (i.e. collective LCFs) to potential truck traffic accident fatalities from causes other than radiological exposure. For further comparison

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[13] The accident probability (risk) on any route is the sum of the accident probabilities for the route through each state transited. These state accident probabilities are calculated by multiplying the route kilometers in each state (from Table A-9) by the accidents per km for that state (from Table A-15).

[14] The analysis is based on either cask type because both have the same legally-defined maximum external dose rate (0.1 mSv/hour (10 mrem/hour) at two meters (6.6 feet) from the cask (10 CFR 71.47(b)(3)) to which it is conservatively assumed that members of the public would be exposed. Therefore, exposure to either cask type in the type of accident evaluated in this section results in essentially the same radiological impact to individual receptors, as illustrated in Table A-7. In actual practice, the external dose rates from these casks would probably be lower than the legally-defined maximum.

Table A-17 Estimated Collective Population Doses and LCFs for an Accident with an Undamaged Cask for Representative Transportation Routes to Disposal by Alternative

ORIGIN NPP LOCATION	MEASURES OF POTENTIAL RADIOLOGICAL IMPACTS	RESULTS BY ALTERNATIVE				
		1A and 1B[a]	2 and 3 (After Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B[a]
Indian Point, NY	**Collective Dose (person-mSv)**	0.143	0.143	0.113	0.740	0.113
	Collective Dose as % of Collective Average Annual Background[b]	0.006%	0.005%	0.004%	0.028%	0.005%
	Collective LCF	8.6E-06	8.6E-06	6.8E-06	4.4E-05	6.8E-06
	Estimated Annual Traffic Fatalities Involving Spent IER Shipments[c]	0.01	0.01	0.01	0.06	0.01
	Collective LCF as % of Projected Annual Traffic Fatalities Involving Spent IER Shipments	0.086%	0.086%	0.068%	0.074%	0.068%
	Collective LCF as % of 2010 Estimated U.S. Cancer Fatalities[d]	1.5E-09%	1.5E-09%	1.2E-09%	7.7E-09%	1.2E-09%
Dresden, IL	**Collective Dose (person-mSv)**	0.150	0.0752	0.0594	0.390	0.0594
	Collective Dose as % of Collective Average Annual Background	0.007%	0.003%	0.003%	0.017%	0.003%
	Collective LCF	9.0E-06	4.5E-06	3.6E-06	2.3E-05	3.6E-06
	Estimated Annual Traffic Fatalities Involving Spent IER Shipments	0.01	0.01	0.005	0.03	0.005
	Collective LCF as % of Projected Annual Traffic Fatalities Involving Spent IER Shipments	0.090%	0.045%	0.071%	0.078%	0.071%
	Collective LCF as % of 2010 Estimated U.S. Cancer Fatalities	1.6E-09%	7.9E-10%	6.3E-10%	4.0E-09%	6.3E-10%
Palo Verde, AZ	**Collective Dose (person-mSv)**	0.228	0.0330	0.0261	0.172	0.0261
	Collective Dose as % of Collective Average Annual Background	0.01%	0.001%	0.001%	0.006%	0.001%
	Collective LCF	1.4E-05	2.0E-06	1.6E-06	1.0E-05	1.6E-06
	Estimated Annual Traffic Fatalities Involving Spent IER Shipments	0.02	0.002	0.002	0.01	0.002
	Collective LCF as % of Projected Annual Traffic Fatalities Involving Spent IER Shipments	0.069%	0.099%	0.078%	0.103%	0.078%
	Collective LCF as % of 2010 Estimated U.S. Cancer Fatalities	2.5E-09%	3.5E-10%	2.8E-10%	1.8E-09%	2.8E-10%
Vogtle, GA	**Collective Dose (person-mSv)**	0.226	0.0729	0.0261	0.378	0.0576
	Collective Dose as % of Collective Average Annual Background	0.01%	0.003%	0.001%	0.014%	0.003%
	Collective LCF	1.4E-05	4.4E-05	1.6E-06	2.3E-05	3.5E-06
	Estimated Annual Traffic Fatalities Involving Spent IER Shipments	0.01	0.01	0.002	0.03	0.005
	Collective LCF as % of Projected Annual Traffic Fatalities Involving Spent IER Shipments	0.136%	0.044%	0.078%	0.076%	0.069%
	Collective LCF as % of 2010 Estimated U.S. Cancer Fatalities	2.5E-09%	7.7E-09%	2.8E-10%	4.0E-09%	6.1E-10%

[a] The collective doses for Alternatives 1A and 1B and Alternatives 4A and 4B are the sums of the collective dose from the NPP to the waste processing facility and from the processing facility to disposal.

[b] The collective dose as a percentage of collective average annual background was calculated by dividing the annual collective dose by the annual collective background dose to the suburban population from Table A-13 times 3.6 person-mSv/year (Shleien et al., 1998), and multiplying by 100 to obtain a percentage.

[c] From Table A-16.

[d] Based on 569,495 estimated cancer fatalities in the United States in 2010 (American Cancer Society, 2010).

purposes in the table, collective LCFs are calculated as percentages of 2010 total estimated U.S. cancer fatalities.

Table A-17 shows that even assuming a stop as long as 10 hours, the estimated collective doses are small fractions of the U.S. average annual background dose and the corresponding LCFs are very low and several orders of magnitude lower than the estimated number of traffic fatalities from spent IER shipments and 2010 estimated U.S. cancer fatalities. There is little variation between these results for the various alternatives and representative transportation routes. The dose to, and corresponding LCF for, the nearest member of the public, the MEI, for this type of accident are 1.3×10^{-4} mSv and 7.8×10^{-9}, respectively, and are the same regardless of transportation route, accident location, or alternative. This dose and LCF are 0.013 percent of background and 2.3×10^{-8} percent of 2010 total estimated U.S. cancer fatalities, respectively. Thus, the potential radiological impacts to individuals and populations from this type of accident would be SMALL.

A.3.3.2.2 Accidents in Which Radioactive Material Could Be Released

This section separately examines the consequences of accidents involving Type A and Type B casks in which radioactive material could be released. Due to design differences between these two types of shipping casks and the different classes of waste they would carry, the consequences of such accidents involving these two cask types would be different. Type A casks are the less robust in design of the two and, therefore, more likely to be damaged in an accident, but would carry the lower activity Class A spent IERs. Type B casks, which would carry the higher activity Class B and C IERs, are very robust and designed to withstand severe accidents. Note also that accident consequences for each cask type are evaluated for a single accident of each kind and not for each of the six alternatives. This is because, as illustrated in Table A-15, the numbers of tractor-trailer truck accidents that occur is extremely low and the likelihood of even one such accident occurring is very small.

Accidents in Which a Type A Cask Would be Impacted

This section examines the potential impact on members of the public if a Type A cask is in an accident that is severe enough to damage the cask and expose the public to the entire spent IER contents of the cask. The test series required for Type A casks such as the CNS 14-215 in 10 CFR 71.71 ensures that these casks can withstand the stresses and strains of routine transportation, but not necessarily survive severe accidents. Consequently, the radionuclide inventory[15] that can be carried in a Type A cask is limited by regulation; specifically, the radionuclide inventory than can be transported in a Type A cask cannot not exceed the A_2 value defined in 10 CFR 71, Appendix A, Table A-1.

The A_2 values were calculated using the “Q system” defined by the International Atomic Energy Agency (IAEA, 2002; Appendix I, Section I.11, pp. 216 et seq.), which is based on a set of

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[15] Radionuclide inventory is the list of radionuclides in a particular material and the radioactivity of each. In this document, the radionuclide inventory is expressed in curies.

exposure scenarios called the “Q series”. The “Q” in the term Q system stands for “quantity”. The Q system defines the quantity limits of radionuclides (e.g., in terms of A_2 values) that are allowed in a Type A package. As discussed below, the analysis in this section uses the Q system to define the basis for exposure to a release of spent IERs from a Type A cask severely damaged in a transportation accident. Spent IERs are contaminated with radionuclides throughout their volume, and the amount that can be carried in a Type A cask is defined by the A_2 values.

There are five IAEA Q series exposure scenarios:

- Q_A - exposure to external gamma radiation;
- Q_B - exposure to external beta radiation;
- Q_C - exposure to radioactive material by inhalation, resulting in an internal dose;
- Q_D - skin contamination by, and ingestion doses from, radioactive material; and
- Q_E - exposure by submersion in a cloud of radioactive material.

The IAEA Q series scenarios are based on a person exposed to an A_2 quantity of radioactive material in any one of the Q series scenarios receiving a radiation dose no greater than 50 mSv (5000 mrem) if that person is located one meter from the A_2 quantity for 30 minutes. Thus, if a Type A cask carrying an A_2 quantity of material is in an accident so severe that a person standing one meter from the cask is exposed to the entire contents of the cask for 30 minutes, he or she would receive a dose of ionizing radiation that is at most 50 mSv. Under these conditions, a dose of 50 mSv is considered acceptable by the IAEA. The A_2 values from the Q series, which limit the types and amount of radionuclides that can be transported in a Type A package, are based on these criteria. Although it is acknowledged that 50 mSv is a sizeable dose of radiation, IAEA considers this dose to be acceptable based on the assumption that no one would remain as close as a meter to an A_2 amount of radioactive material.

The above information and considerations may be used to calculate the dose to a receptor at any distance from a source (e.g., the A_2 amount potentially released from a damaged Type A cask in an accident) for any period of time. The radiological risks and consequences of accidental releases of radioactive material depend on the radionuclide inventory in the shipping cask. Radiation dose is inversely proportional to the square of the distance of the receptor from the radiation source and directly proportional to the amount of time the receptor spends at that distance. The dose to a receptor is also directly proportional to the total radioactivity to which the receptor is exposed. This scheme is used in this analysis to calculate the radiation dose to a receptor if a Type A package carrying its maximum A_2 quantity of spent IERs (the maximum quantity allowed) is severely damaged in an accident and the receptor is exposed to the entire contents of the cask.

It is further assumed that spent IERs transported in a Type A cask would not be dispersed in the air if the cask were severely damaged and, therefore, the public would only be externally exposed to the spent IERs (i.e., the IERs would not be inhaled or ingested). Physical characteristics of spent IERs are such that atmospheric dispersion is highly unlikely. A typical IER, Purolite® NRW3240, has a density of 705 to 740 grams per liter and a particle size range of 425 to 1200 micrometers (μm) (Purolite, 2012). Although the densities of many aerosolizable materials are similar (e.g., the density of water is 1000 grams per liter), typical aerosolizable particle size is less than 50 μm, much smaller than typical IER particle size. Thus, the spent IERs from a damaged Type A cask released to the environment would most likely remain on the ground at the site of the accident rather than being dispersed because of their larger particle size. Thus, the Q_A scenario, external gamma dose to a receptor, is the most likely exposure scenario for this damaged Type A cask accident case, and the dose from a damaged Type A cask carrying spent IERs to a member of the public is calculated in the present analysis based on the Q_A scenario for external radiation exposure. The progression of this analysis is detailed below.

Table A-18 provides basic data and intermediate calculations for the accident analysis, which are the projected annual average radionuclide inventories of spent IERs per boiling water reactor (BWR) unit and per pressurized water reactor (PWR) unit and the calculated A_2 values of the mixtures.[16]

The numbered columns in the table are as follows:

Column 1: Radionuclides that could be released in an accident involving the Type A cask.

Column 2: A_2 value for each radionuclide.

Column 3: Average annual radionuclide Ci content of spent IERs per BWR unit.

Column 4: Average annual radionuclide Ci content of spent IERs per PWR unit.

Column 5: Fraction of total BWR Ci represented by the activity of each radionuclide.

Column 6: Fraction of total PWR Ci represented by the activity of each radionuclide.

Column 7: Ratio of each BWR radionuclide fraction to its A_2 value.

Column 8: Ratio of each PWR radionuclide fraction to its A_2 value.

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[16] It is important to distinguish between spent IERs from boiling water reactors (BWRs) and those from pressurized water reactors (PWRs) in this analysis because the radionuclide inventories from these two sources would be different and the public would be exposed to the actual radionuclide inventory. In general, the curie content (i.e., amount of radioactivity) of BWR spent IERs is slightly higher than that of PWR spent IERs.

Table A-18 Radionuclide Inventories of BWR and PWR Spent IERs and Calculation of the A_2 Values of the Mixtures

1	2	3	4	5	6	7	8
RADIO-NUCLIDE	**A_2(i) VALUE**	**BWR[a] (Ci)**	**PWR[b] (Ci)**	**BWR Fraction**	**PWR Fraction**	**BWR f(i)/A_2(i)**	**PWR f(i)/A_2(i)**
H-3[c]	0.54	0.54	0.8	1.29E-03	5.94E-03	2.40E-03	1.10E-02
C-14	81	0.72	0.55	1.73E-03	4.08E-03	2.13E-05	5.04E-05
Cr-51	810	2.8	0.043	6.71E-03	3.19E-04	8.28E-06	3.94E-07
Mn-54	27	25	3.4	5.99E-02	2.52E-02	2.22E-03	9.35E-04
Fe-55	1100	240	22	5.75E-01	1.63E-01	5.23E-04	1.48E-04
Fe-59	24	0.42	0.018	1.01E-03	1.34E-04	4.19E-05	5.57E-06
Co-57	270	0.0072	0.37	1.73E-05	2.75E-03	6.39E-08	1.02E-05
Co-58	27	2.4	18	5.75E-03	1.34E-01	2.13E-04	4.95E-03
Co-60	11	110	12	2.64E-01	8.91E-02	2.40E-02	8.10E-03
Ni-59	--[d]	0.24	0.07	5.75E-04	5.20E-04	--	--
Ni-63	810	4.3	43	1.03E-02	3.19E-01	1.27E-05	3.94E-04
Zn-65	54	16	0.016	3.83E-02	1.19E-04	7.10E-04	2.20E-06
Sr-90	8.1	0.18	0.094	4.31E-04	6.98E-04	5.32E-05	8.62E-05
Zr-95	22	0.027	0.036	6.47E-05	2.67E-04	2.94E-06	1.21E-05
Nb-94	19	0.00	5.40E-07	0.00	4.01E-09	0.00	2.11E-10
Tc-99	24	0.00002	0.00017	4.79E-08	1.26E-06	2.00E-09	5.26E-08
Ag-110m	11	0.063	0.034	1.51E-04	2.52E-04	1.37E-05	2.29E-05
Sb-125	27	0.34	0.034	8.15E-04	2.52E-04	3.02E-05	9.35E-06
Cs-134	19	0.027	0.93	6.47E-05	6.90E-03	3.40E-06	3.63E-04
Cs-137	16	1.3	13	3.11E-03	9.65E-02	1.95E-04	6.03E-03
Ce-144	5.4	12	20	2.88E-02	1.48E-01	5.32E-03	2.75E-02
Pu-238	0.027	0.9	0.29	2.16E-03	2.15E-03	7.99E-02	7.97E-02
Pu-239/240	0.027	0.002	0.00073	4.79E-06	5.42E-06	1.77E-04	2.01E-04
Pu-241	0.027	0.00033	0.00026	7.91E-07	1.93E-06	2.93E-05	7.15E-05
Am-241	0.027	0.077	0.0034	1.84E-04	2.52E-05	6.83E-03	9.35E-04
Cm-242	0.27	0.00029	0.00045	6.95E-07	3.34E-06	2.57E-06	1.24E-05
Cm-243	0.027	0.0014	0.00035	3.35E-06	2.60E-06	1.24E-04	9.62E-05
Cm-244	0.054	0.0011	0.00059	2.64E-06	4.38E-06	4.88E-05	8.11E-05
Total Ci Content		**417**	**135**		**Total *f(i)/A_2(i)***	**0.116/Ci**	**0.140/Ci**
[redacted]					——— ——	**8.61 Ci**	**7.15 Ci**

Sources: (EPRI, 2007; Table 6-13) and 10 CFR 71 Appendix A (see text).

[a] BWR = boiling water reactor

[b] PWR = pressurized water reactor.

[c] A_2 value for this radionuclide is from 10 CFR 71, Appendix A, Table A-3.

[d] There is no useable A_2 value for this radionuclide.

The radionuclide inventory and curie (Ci) content data is from EPRI (EPRI, 2007; Table 6-12), and the A_2 values of the radionuclides are from Table A-1 of 10 CFR Part 71, Appendix A. The information in Table A-18 does not distinguish between Class A, B, and C concentration spent

IERs because there are no radionuclide inventory data available for the individual classes of the spent IERs.

In Table A-18, the following formula from 10 CFR 71, Appendix A, is used to calculate the A_2 values of the mixtures of BWR and PWR spent IER radionuclides:

In this equation, *f(i)* is the fraction of activity of radionuclide *i* in the cask and $A_2(i)$ is the A_2 value of the radionuclide *i.* The results of the calculations using this equation are shown at the bottom of the table. These are the maximum A_2 values of the spent IER mixtures allowed to be carried in a Type A cask.

As discussed earlier, the A_2 value for a Type A cask shipment is based on a dose of 50 mSv to a person one meter from the damaged cask for 30 minutes. From this, the dose to a person located at a different distance from an actual damaged cask for a different period of time can be calculated. The representative dose, D(*r, t*), to a receptor located closest to the site of an accident involving a single Type A spent IER shipment in which the cask is damaged and all of its contents are released, is calculated using the following equation:

In this equation, *C* is the curies per shipment; *t* is the exposure time; A_2 is the A_2 value of the spent IER mixture in the cask; and *r* is the distance of the receptor from the cask. K is a constant based on the IAEA Q_A exposure scenario of a 50-mSv dose to a person one meter from the damaged cask for 30 minutes (0.5 hour (hr)), and is given by:

For this analysis, the calculations are based on the following additional parameters and assumptions, similar to those used in RADTRAN calculations of radiological impacts to individual receptors near truck stops:

- The accident occurs on an interstate highway, and is outside with no shielding.
- The closest member of the public to the accident (the MEI) would be 30 meters away (from Table A-6).
- The exposure lasts for 10 hours (hr) (from Table A-6).

For this analysis, the maximum curie content per Type A spent IER shipment is assumed be the A_2 value derived in Table A-18, i.e., 8.61 Ci for BWR shipments and 7.15 Ci for PWR shipments.

With this conservative assumption that the Type A casks carrying the A_2 values are involved in an accident, and using the information in the three bullets above for accident conditions, exposure time, and distance, the estimated dose received by the nearest receptor to a damaged Type A cask carrying BWR spent IERs, D_{BWR}, is:

The dose for a cask containing PWR spent IERs is similarly calculated and produces the same result, since the PWR IER cask is also carrying A_2 curies. LCFs are calculated from the doses as discussed earlier in this appendix. Dose and LCF results are summarized in Table A-19, compared with average annual background and 2010 total estimated U.S. cancer fatalities, respectively.

As shown in Table A-19, the MEI dose and LCF as percentages of U.S. average annual background and 2010 U.S. total estimated cancer fatalities are 31 percent and 1 x 10^{-8} percent, respectively, for either reactor type. These results indicate that potential radiological impacts to an individual exposed to spent IERs released from a damaged Type A cask in a truck accident would be SMALL. Collective doses were not calculated because the IAEA Q series is based on individual dose, not collective dose.

Table A-19 Estimated Doses and LCFs to an Individual Receptor for an Accident Involving a Damaged Type A Cask by NPP Reactor Type

MEASURES OF POTENTIAL RADIOLOGICAL IMPACTS	REACTOR TYPE	
	BWR	PWR
MEI Dose (mSv)	1.11	1.11
MEI Dose as % U.S. Annual Background[a]	31%	31%
MEI LCF	6.7E-05	6.7E-06
MEI LCF as % 2010 Estimated U.S. Cancer Fatalities[b]	1E-08%	1E-08%

[a] Based on average annual U.S. background dose of 3.6 mSv/year (Shleien et al., 1998).

[b] Based on 2010 total estimated cancer fatalities in the U.S. of 569,495 (American Cancer Society, 2010).

Accidents in Which a Type B Cask May Be Impacted

Spent IERs that exceed the A_2 limit must be carried in Type B casks. For this evaluation, it is assumed that the Class B and C resins would be shipped in these casks. Type B casks are designed to be sufficiently robust that they are not likely to be damaged in a traffic accident. The degree of robustness is ensured by the NRC regulations in 10 CFR Part 71. The test series of 10 CFR 71.73 required for Type B casks subjects these casks to conditions generally more severe than a very bad traffic accident (Sprung et al., 2000), thus ensuring that the cask can withstand the stress of a traffic accident. Therefore, release of radioactive material from a Type B cask could occur only in accidents considerably worse than almost all traffic accidents. Such accidents would involve extremely severe impacts of casks onto hard targets, or a very long-lasting, very hot fire, or both. Even such extreme conditions would not damage the body of the cask (although the cask's lead shielding might be slightly damaged); and releases of radioactive material, if any, could occur only through the cask seals and then only in very small quantities (Sprung et al., 2000; Chapters 7 and 8). Thus, the only way in which spent IER material released from a Type B cask could result in a radiation dose to a member of the public is if the material could be dispersed from damaged cask seals as very small, aerosol-sized particles. Larger particles would be too large to escape through the seals.

From among the six alternatives, the only spent IERs that could potentially be released through damaged Type B cask seals as aerosolized particles could be those that are thermally processed (blended or volume-reduced) and transported to a waste disposal site in Alternatives 1B, 4A, and 4B. In Alternative 1B, the processed (blended) resins would be Class A LLRW when shipped for disposal, thus not shipped in a Type B cask; however, in Alternatives 4A and 4B, the volume-reduced resins would be Class B or C waste. These thermally processed resins would be the only materials to be transported that would be dry (water free) form. As noted in Section 4.2.2, this final, thermally processed waste form appears to be granular to powdery. Prior to thermal processing in Alternatives 1A, 4A and 4B, in all other stages of these three alternatives, and in all stages of Alternatives 1A, 2 and 3, the spent IERs in transport would not be in aerosolizable form. Although excess water will have been removed to varying degrees from the spent IERs (see Section 4.1.1), it is reasonably assumed that these resins, which had not been thermally processed, would not readily aerosolize and, therefore, would not be released through the seals because they would not be sufficiently dry and, more importantly, they would be in relatively large, bead-like form (see Section 2.1.1).

Note, however, that information on the physical properties of the final, thermally processed spent IERs in Alternatives 1B, 4A, and 4B is not available. Therefore, for this evaluation, it is conservatively assumed that there might be sufficiently fine material present in this final waste form that could aerosolize through damaged Type B cask seals. However, if thermally processed spent IERs do not contain any sufficiently fine, powdery material, then this evaluation overestimates actual impacts.

There is no published model for the accidental release of spent IERs, or similar LLRW, in aerosolized form from damaged seals of a Type B cask. The only current published model of such releases of radioactive material from a Type B cask is that of potential release of NPP spent nuclear fuel (SNF) particles and of corrosion products that are on the outer surface of SNF elements (Sprung, et al, 2000; Chapter 7) (hereafter call the "SNF model"). This model is adapted for in this analysis and used in association with the RADTRAN accident model to assess potential radiological impacts of spent IER releases.

It is very important to note that the radioactivity levels of the Class A, B, and C LLRW spent IERs are orders of magnitude lower than that of SNF materials. For example, Cesium-137 (Cs-

137) is present in SNF in concentrations on the order of 10^5 Ci per fuel assembly (DOE, 2002; Appendix A, Tables A-8 and A-9). However, the Ci content of Cs-137 in a spent IER shipment in a Type B cask would be about one curie or less, and the total curie content in a Type B cask carrying BWR Class B and C resins would be about 12 Ci or less (see Table A-21 later in this section).

In modeling spent IER releases using the SNF model, it is necessary to consider the following additional, noteworthy differences between the SNF model and the nature and behavior of thermally processed spent IERs, and differences in the Type B casks used for SNF and spent IER transport, which lead to the development of assumptions in the spent IER modeling:

- Pressure differentials: Sealed Type B casks used for SNF transport have a naturally slightly higher internal pressure than ambient atmospheric pressure (due to the elevated temperatures of SNF over ambient temperatures), so that if breached, particles would be driven out of the casks by the pressure differential. However, in the case of the spent IERs, the internal pressures in the Type B transportation casks are expected to be about the same as the ambient atmospheric pressure, so that there would be no internal force within the casks that would drive out the resin particles. Thus, smaller amounts of spent IERs would be released through damaged cask seals.

- Particle sizes: Studies of SNF have established a range of particle sizes for spent fuel and for the particulate corrosion products that are on the surface of spent fuel rods (Einziger, 2007; Einziger and Beyer, 2007; Hanson et al., 2008). These particles can be released through a breach in the seals with only a small pressure differential (Einziger, 2007). However, the particle size range for thermally processed spent IERs is not available. It is assumed for this analysis that the particle sizes of these IERs are similar to those of SNF and associated corrosion products.

- Gaps in cask seals: Sprung et al. (2000) studied the gaps in SNF cask seals that result from very severe accidents. However, no such documentation exists for the CNS8-120B Type B casks used for Class B and C spent IER transport. It is assumed for this analysis that the behavior of the cask seals in a CNS8-120B is similar to that of SNF casks.

- Gaseous radionuclides: While radionuclides in the gas phase are present in SNF, in the process spent IER material they would have been released during high temperature thermal processing and, therefore, would not be present in the shipping casks.

Accidents differ in the amount of stress on the cask and in the amount of material that could be released. Following the practice first used by the NRC in NUREG-0170, "Final Environmental Impact Statement for the Transportation of Radioactive Material by Air and Other Modes" (NRC, 1977), and used subsequently in other environmental impact assessments and studies of this type (Fischer et al., 1987; Sprung et al., 2000; DOE, 2002, Appendix J), six different types of accidents, of varying severity and a range of release fractions, are postulated in this analysis. The release fractions (i.e., the fraction of total radioactivity in the cask released for that particular accident scenario) associated with these accident scenarios are intended to include most of the extremely severe transportation-related accidents possible (DOE, 2002; Appendix J). Table A-20 lists these accident scenarios and their associated conditional probabilities (i.e., the probabilities of particular accident scenarios in the event of an accident) and release fractions for the SNF corrosion products and spent fuel particles. Note that all of the release fractions are very low, indicating that extremely small of amounts of the cask contents would be released to the environment.

Table A-20 The Six Accident Scenarios and Associated Conditional Probabilities and Release Fractions

SCENARIO DESCRIPTION	SCENARIO INDEX	APPROXIMATE CONDITIONAL PROBABILITY[a]	FRACTION OF Ci INVENTORY RELEASED	
			Corrosion Product Particles	Spent Fuel Particles [c]
No release[b]	1	0.9999	0.00	0.00
Low-speed impact (less than 90 mph) into hard target	2	6.1E-05	1.36E-03	1.02E-07
High-speed impact (greater than 90 mph) into hard target	3	5.9E-06	2.52E-03	6.71E-08
Truck fire exposing the cask	4	5E-07	1.83E-03	3.37E-07
Truck fire exposing the cask with low-speed impact into hard target	5	7.5E-08	3.16E-03	3.77E-06
Truck fire exposing the cask with high-speed impact into hard target	6	3E-10	3.17E-03	5.01E-06

Source: Sprung, 2007; Chapter 7.

[a] The conditional probability is the probability of the particular accident scenario in the event of an accident.

[b] This scenario, which is analyzed in Section A.3.3.2.1 above, is included to provide a complete accident scenario picture, and to show the most likely accident scenario in relation to the other accident scenarios. It also reinforces that in 99.99% of Type B cask accidents, no radioactive inventory is released.

[c] The release fractions for spent fuel particles are not included in the analysis because they are three or more orders of magnitude less than the release fractions for corrosion product particles, and therefore would not affect the analysis results.

In this evaluation, the RADTRAN accident analysis is conducted only for the most severe accident scenario—Scenario Index 6: “Truck fire exposing the cask with high-speed impact into hard target”—because that is the scenario with the highest release fraction of the six (3.17×10^{-3}) and, therefore, would yield the most conservative impact analysis results. The data in Table A-20 are some of the user defined input parameters to the RADTRAN accident analysis. Other input parameters to RADTRAN for radiation dose calculation from a transportation accident involving a Type B (CNS8-120B) cask, which are usually defined by the analyst, are identified and discussed below. These input parameters are based on some assumptions because the radionuclide inventory of each individual cask of thermally processed spent IERs is not precisely known, the behavior of the processed spent IER material under accident conditions has not been studied, and a specific location of the modeled accident is not defined for the present generic, non-location specific evaluation.

Note also that the accident is not specifically analyzed for each of the alternatives because the only difference between the alternatives is the number of shipments. In fact, the severe accidents listed in Table A-20 are unlikely to occur at all because the probabilities of their occurrence are extremely low (less than one in a million in most cases). Thus, such accidents are highly unlikely to occur more than once for any alternative. Further, for reasons discussed above, the Type B cask accident scenario analyzed would apply only to Alternatives 1B, 4A, and 4B. However, the release is analyzed in this appendix only for the processed resins from Alternatives 4A and 4B because only these alternatives include higher activity Class B or C spent IERs that would be in a dry (water free), aerosolizable form as a result of thermal processing and could be released through the cask seals and dispersed in a severe accident.

The RADTRAN model input for this analysis is derived from the RADCAT 3.0 User Guide (Weiner et al., 2009) and other sources (Sprung et al., 2000 (Chapter 7); DOE, 2002 (Chapter 6 and Appendix J)). The input parameter values are for the release of particulate corrosion products from an SNF Type B cask. The additional RADTRAN inputs specific to this calculation are:

- Release of material at ground level
- U.S. average meteorology (from which to calculate dispersion): Pasquill stability D, 4.7 meters/second (m/sec) wind speed
- Accident location in urban area (with population density 2500 persons/km^2)[17]
- Distance of maximally exposed individual (MEI) from truck: 30 m (from Table A-5)
- Aerosol fraction: 1 (i.e., all particles released into the environment are aerosolized)
- Respirable fraction[18] of aerosolized particles: 0.05[19]
- Particle deposition velocity: 0.01 m/sec.[20]

In an average year, 17,760 curies of spent IERS are generated from BWRs and 9,256 curies of spent IERs are generated from PWRs (from EPRI, 2007, Table 6-12). Because no data are

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[17] These parameters are conservative because the largest impacts from the postulated accidents would occur in urban areas where population densities are the greatest. Also, the selected population density is near the top of the range of the urban population densities along the representative transportation routes discussed in Section A.3.2.2 (see Table A-7). In addition, the population density is assumed to exist under the entire plume, from the location of the accident out to 120 km (about 75 miles).

[18] Respirable fraction is the fraction of the aerosol that receptors would inhale all the way into their lungs, on average.

[19] Based on RADTRAN model constraint.

[20] Based on RADTRAN model constraint.

available to determine what fraction of these curies would be shipped in a Type A or Type B cask, it was conservatively assumed for the analysis in this section that all of these curies are shipped in Type B packages. This is conservative because some fraction of these curies is lower activity and could be shipped in Type A casks.

In the calculation, the number of annual BWR or PWR Type B shipments is first determined by dividing the volume of Class B plus Class C spent IERs (from Table 2 of Section 2.3.1) by the volume of one Type B cask. The curies per Type B shipment for PWRs and BWRs is then determined by dividing the annual curies of spent IERs (17,760 curies from BWRs and 9,256 curies from PWRs) by the calculated number of annual BWR or PWR Type B shipments.

The number of BWR or PWR Type B shipments and curies per shipment is calculated as follows:

# of BWR Type B Shipments:

# of PWR Type B Shipments:

BWR Type B Curie Content per Shipment:

PWR Type B Curie Content per Shipment:

The fractions of total curies represented by each radionuclide (from Table A-18, columns “BWR Fraction” and “PWR Fraction”) are multiplied by the BWR and PWR curies per shipment, then corrected for the absence of tritium (H-3) and C-14 in the shipments.[21] The total BWR and PWR curies per Type B shipment are then 466 Ci and 126 Ci, respectively. The curie inventories are shown in Table A-21. These curie amounts are used in the accident analysis.

The results (consequences) of the analysis of the modeled release for the “Truck fire exposing the cask with high-speed impact into hard target” accident scenario are shown in Table A-22. As is evident from the low MEI and collective (population) dose and LCF percentages of

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[21] Tritium and C-14 would have been driven off as gases during thermal processing in Alternatives 4A and 4B.

background and 2010 estimated U.S. cancer fatalities, respectively, a release and subsequent dispersion of spent IER material as a result of a transportation accident involving a Type B cask would result in a SMALL impact.

Table A-21 Calculated Curie Inventories of a Single BWR and Single PWR Type B (CNS 8-210B) Cask Shipment

RADIONUCLIDE[a]	BWR CURIES	PWR CURIES
Cr-51	3.50	0.0401
Mn-54	32.4	3.19
Fe-55	284	20.5
Co-57	7.50E-03	0.349
Co-58	2.66	17.0
Fe-59	0.521	0.0162
Ni-59	0.212	0.159
Co-60	111	11.6
Ni-63	4.29	40.8
Zn-65	14.3	.0149
Sr-90	0.163	0.0877
Zr-95	0.0989	0.0378
Nb-94	1.70E-05	1.79E-04
Tc-99	0.0576	0.0321
Ag-110m	0	0
Sb-125	0.30	0.0368
Cs-134	0.18	0.892
Cs-137	1.11	11.7
Ce-144	10.2	18.8
Pu-238	0.813	0.274
Pu-239/240	0	1.71E-06
Pu-241	1.82E-03	7.08E-04
Am-241	3.0E-03	2.55E-04
Cm-242	0.0803	0.0327
Cm-243	2.60E-03	4.23E-04
Cm-244	1.23E-03	3.66E-04
Total	**466**	**126**

[a] H-3 and C-14 would be present in the spent IER mixture as water and CO_2 and would therefore not be present in the processed material.

Table A-22 Consequences of Dispersion of Spent IERs from Accidental Release from a Type B Cask for Accident Scenario Index 6 from Table A-20

MEASURES OF POTENTIAL RADIOLOGICAL IMPACTS	REACTOR TYPE	
	BWR	PWR
MEI Dose (mSv)	0.60	0.20
MEI Dose as % of U.S. Annual Background	17%	5.6%
MEI LCF	3.5E-05	1.2E-05
MEI LCF as % of 2010 Estimated U.S. Cancer Fatalities	6E-09%	2E-09%
Collective (Population) Dose (person-mSv)	19.9	6.16
Collective Dose as % of U.S. Annual Background	0.22%	0.068%
Collective LCF	1.2E-03	3.6E-04
Collective LCF as % of 2010 Estimated U.S. Cancer Fatalities	2E-07%	7E-09%

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