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

Final Report

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**U.S. Nuclear Regulatory Commission**

**Office of Federal and State Materials and Environmental  
Management Programs**

**September 2013**

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

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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 lesser magnitude than described in this report.

Ion exchange resins are powdered or 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—located near Richland, Washington, near Barnwell, South Carolina, in Clive, Utah, and near Andrews, Texas. The Clive facility is licensed to dispose of, and could accept, Class A LLRW from all 50 states.<sup>1</sup> The Richland and Barnwell facilities are licensed to dispose of Class A, B, and C LLRW, but can accept these wastes only from a limited number of states. The Andrews facility, which commenced operations on April 27, 2012, can accept Class A, B, and C LLRW from Texas and Vermont and from individual generators in out-of-compact states on a case-by-case basis and subject to annual 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, and potentially have access to a disposal facility for their Class B and C spent IERs at this time. Note, however, that the scope of the evaluation presented in this report was established at an earlier time when the majority of NPPs had no access, or limited access, to Class B and C disposal.

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<sup>1</sup> Although the Clive facility in the Northwest Compact could accept Class A LLRW from all 50 states, the Rocky Mountain and Northwest Compacts require their generators to send Class A LLRW to the facility located near Richland, Washington.

LLRW processing and waste disposal companies are exploring alternatives for managing Class B and C concentration spent IERs.<sup>2</sup> 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.

On September 20, 2012, the NRC staff published a notice in the *Federal Register* requesting public comments on the “Draft Comparative Environmental Evaluation of Alternatives for Handling Low-Level Radioactive Waste Spent Ion Exchange Resins from Commercial Nuclear Power Plants” (Draft Report). The 120-day public comment period ended on January 18, 2013. This Final Report has been prepared considering, and providing responses to, all the comments received, and includes revisions to the report based on some of these comments.

## 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.

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<sup>2</sup> 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 Part 20 Appendix G do not require LLRW to be classified until it is shipped for disposal.

- 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.
- 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<sup>3</sup>, 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.

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<sup>3</sup> Agreement States are states that have assumed specific 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.

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 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 that are listed or 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, as required, 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), and dose-based requirements under 10 CFR 20.1301), 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 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.

Spent IERs would be transported to waste processing and disposal facilities on public roadways in special shipping casks (assumed for reasons discussed in the report to be 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<sup>4</sup> 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

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<sup>4</sup> 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.

measured in units of millisieverts (mSv) or millirem (mrem). Individual receptors are persons at 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<sup>5</sup>), 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.<sup>6</sup> 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.

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<sup>5</sup> 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.

<sup>6</sup> 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, from natural sources, of 3.11 mSv/year (311 mrem/year), as a percentage of the background dose. For populations, the annual collective dose is compared to 3.11 mSv (311 mrem) 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.

- Radiological Impacts of Routine Transportation. For individuals, the highest estimated doses (as calculated using RADTRAN 6) and corresponding LCFs would be to the “maximally exposed individual”, or MEI<sup>7</sup>, 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 0.08 percent of the average annual U.S. background radiation dose; and the corresponding LCFs would be negligible, ranging from about  $1 \times 10^{-11}$  to  $3 \times 10^{-11}$  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 0.058 to 0.14 percent of the background dose, and the corresponding LCFs would range from  $2 \times 10^{-11}$  to  $5 \times 10^{-11}$  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  $5 \times 10^{-5}$  to  $10^{-4}$  percent of the U.S. average annual background radiation dose; and corresponding LCFs would be negligible, ranging from about  $1 \times 10^{-10}$  to  $3 \times 10^{-9}$  percent of 2010 total estimated U.S. cancer fatalities. For trucks at rest and refueling stops, maximum annual collective population doses from stationary trucks would range from about 0.1 to 0.2 percent of background; and corresponding LCFs would be negligible, ranging from about  $1 \times 10^{-8}$  to  $4 \times 10^{-8}$  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

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<sup>7</sup> 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.

is little variation between these results for the various alternatives and transportation routes evaluated.

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  $7.7 \times 10^{-9}$  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 36 percent and  $1 \times 10^{-8}$  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 19 percent and  $6 \times 10^{-9}$  percent, respectively; and the corresponding collective dose and LCF percentages would be 0.25 percent and  $2 \times 10^{-7}$  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 and dose-based requirements under 10 CFR 20.1301).

## **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.

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## ACRONYMS AND ABBREVIATIONS

AEA	Atomic Energy Act of 1954, as amended
ALARA	as low as reasonably achievable
BMPs	best management practices
BTP	Branch Technical Position
BWR	boiling water reactor
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
Ci	curie
CNS	Chem-Nuclear Systems
CO	carbon monoxide
CO <sub>2</sub>	carbon dioxide
CT	computed tomography
CWF	Containerized Waste Facility
DOE	U.S. Department of Energy
DOT	Department of Transportation
DRC	Division of Radiation Control [of the Utah Department of Environmental Quality]
DWS	drinking water standards
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
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
IP	Industrial Package
ISCORS	Interagency Steering Committee on Radiation Standards
LCF	latent cancer fatality
LLRW	low-level radioactive waste
LSA	low specific activity
MEI	maximally exposed individual
MIMS	Manifest Information Management System
MVS	modular vitrification system
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 <sub>2</sub>	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
PENV	Phoenix Energy of Nevada, LLC
PL	Public Law
PM <sub>10</sub>	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
SDW	Safe Drinking Water
SHPO	State Historic Preservation Officer
SIER	spent ion exchange resins
SNF	spent nuclear fuel
SNL	Sandia National Laboratories
SO <sub>2</sub>	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	<u>TR</u> Ansportation <u>G</u> eographic <u>I</u> nformation <u>S</u> ystem
TRU	transuranic
UCA	Utah Code Annotated
USDOT	U.S. Department of Transportation
USFWS	U.S. Fish and Wildlife Service
VR	volume reduction
WAC	waste acceptance criteria
WCS	Waste Control Specialists LLC

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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 that the conditions necessary for protection must be present; (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, this evaluation identifies and accounts for generally accepted impact mitigation measures in each resource and impact area. As discussed in Section 3 (Scope of Evaluation) of this report, the six alternatives are generic and not location-specific—they are generally not intended to represent any actual actions or facilities. In addition, the 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 of this report, 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 lesser magnitude than described in this report.

At commercial NPPs, IERs are used for water purification. These resins are powdered or 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.<sup>1</sup> These LLRW classes are found in 10 CFR 61.55. Class A LLRW is the lowest activity and least hazardous and Class C LLRW is usually the highest activity and most

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<sup>1</sup>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.

hazardous of the three classes.<sup>2</sup> 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. In accordance with 10 CFR Part 20, Appendix G, LLRW is not required to be classified until 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<sup>3</sup> or the NRC to dispose of one or more classes of LLRW (Low Level Radioactive Waste Policy Amendments Act of 1985, 42 U.S.C. § 2021b),<sup>4</sup> and may also be subject to Low Level Radioactive Waste Compacts<sup>5</sup> 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--located near Richland, Washington, near Barnwell, South Carolina, in Clive, Utah, and near Andrews, Texas, all of which are subject to LLRW Compacts.<sup>6</sup> The Clive facility can accept and dispose of Class A LLRW from all 50 states.<sup>7</sup> The Richland and Barnwell facilities accept and dispose of Class A, B, and C LLRW, but only from a limited number of states. (Tran and James, 2008; Waste Control Specialists, 2009; Waste Control Specialists, 2012; Herness, 2012a) The Andrews facility, which commenced operations on April 27, 2012, can accept Class A, B, and C LLRW from Vermont and Texas as well as from individual generators in out-of-compact states on a case-by-case basis and subject to annual limits (see Section 2.2 for details) (Herness, 2012a; Herness, 2012b; Herness, 2013). Thus, all 65 operating commercial NPPs can currently dispose of their Class A LLRW spent IERs, and potentially have access to a disposal facility for their Class B and C LLRW spent IERs at this time. Note, however, that the scope of the evaluation presented in this report was established at an earlier time when the majority of NPPs had no access, or limited access, to Class B and C disposal.

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<sup>2</sup> Activity is the level of radioactive emissions of a radionuclide, measured in becquerels (internationally) or in curies (in the U.S.).

<sup>3</sup> 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.

<sup>4</sup> 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.

<sup>5</sup> 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).

<sup>6</sup> Additionally, certain very low activity wastes may be disposed in industrial landfills as allowed under 10 CFR 20.2002, and if the receiving facility either possesses a disposal license issued by the NRC or obtains an exemption from the NRC.

<sup>7</sup> Although the Clive facility in the Northwest Compact can accept Class A LLRW from all 50 states, the Rocky Mountain and Northwest Compacts require their generators to send Class A LLRW to the licensed LLRW disposal facility located near Richland, Washington. The only commercial nuclear power plant to which this applies is the Columbia Generating Station, in Richland, Washington.

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 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).

On September 20, 2012, the NRC staff published a notice in the *Federal Register* (77 FR 58416) requesting public comment on the draft of this report, "Draft Comparative Environmental Evaluation of Alternatives for Handling Low-Level Radioactive Waste Spent Ion Exchange Resins from Commercial Nuclear Power Plants" (Draft Report) (NRC, 2012). The 120-day public comment period ended on January 18, 2013. This Final Report considers all of the comments received, and includes revisions to the Draft Report based on some of these comments.

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.
- Appendix B presents all the comments received on the Draft Report and the staff's response to each of those comments.

## 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 are typically powdered or 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<sup>3</sup> (30 ft<sup>3</sup>) each in volume and used in series (a combination of anion, cation, and mixed bed). Activated charcoal may also be added to the resin beds to remove impurities from water. 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.<sup>8</sup> 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.

Construction materials for spent IER containers are selected to be appropriate for storage, shipment, and disposal. 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,<sup>9</sup> and other waste characteristics. There are many sizes (volumes) of the HICs or liners used for spent IER containerization. These HICs or liners are typically placed inside special shipping casks or shipping containers for offsite transport. The type of shipping cask or container used depends on a number of factors, including the mix of radionuclides in the material to be transported and the specific activity of the material. Section 4.1.2.1 and Section A.2.2 of Appendix A provide additional information on the types of containers used for shipping the spent IERs. For reasons detailed in Section A.2.2, this report assumes that the spent IERs are transported in Type A and Type B shipping casks.

Type A casks would be used for transporting lower activity spent IERs whereas Type B casks would be used for higher-activity spent IERS. These two types of shipping casks differ in size, with the Type A cask being the larger of the two. For this evaluation, it is assumed that the liners shipped in Type A and Type B casks have volumes of 5.29 m<sup>3</sup> (187 ft<sup>3</sup>) and 3.17 m<sup>3</sup> (112 ft<sup>3</sup>), respectively (see Table A-1 in Section A.2.2, Appendix A). 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

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<sup>8</sup> At some NPPs, spent IERs are intermediately stored in a spent resin storage tank before being transferred to HICs or liners. Spent IERs of differing concentrations may be mixed in such tanks as part of normal operations.

<sup>9</sup> Specific activity of a radionuclide means the radioactivity of the radionuclide per unit mass of that nuclide. The specific activity of a material in which the radionuclide is essentially uniformly distributed is the radioactivity per unit mass of the material.

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).<sup>10</sup> 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.

**Table 1 Average Annual Volume of Spent IERs Generated by Reactor Type**  
(m<sup>3</sup>/year (ft<sup>3</sup>/year))

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

<sup>a</sup> For a single reactor of each type, based on the average for all reactors of each type.

<sup>b</sup> 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 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<sup>3</sup> (90,620 ft<sup>3</sup>); 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.

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<sup>3</sup> (90,620 ft<sup>3</sup>))

<sup>10</sup> 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.

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

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

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

<sup>a</sup> Based on four years of waste shipping records (2003 through 2006) collected by EPRI from 65 operating nuclear reactors (41 PWRs and 24 BWRs) 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).

## 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.<sup>11</sup> 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 hazard 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).<sup>12</sup> All four of these facilities were licensed and are regulated

<sup>11</sup> 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.

<sup>12</sup> Additionally, certain very low activity wastes may be disposed in industrial landfills as allowed under 10 CFR 20.2002, and if the receiving facility either possesses a disposal license issued by the NRC or obtains an exemption from the NRC.

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, with the exception of those states in the Rocky Mountain and Northwest Compacts, which require their generators to send Class A LLRW to the Richland facility. (Tran and James, 2008; Nuclear Power Daily, 2010) The newest facility, near Andrews, Texas, which commenced operations on April 27, 2012, accepts Class A, B, and C LLRW from the two states in the Texas Compact (Texas and Vermont) (Herness, 2012a). In addition, the Texas Compact has approved individual applications (import petitions) from individual LLRW generators in out-of-compact states to dispose of Class A, B, and C LLRW at the Andrews facility (Herness, 2012b); and effective September 1, 2013, the Texas legislature increased the annual curie limit from 220,000 to 275,000 for Class A, B, and C LLRW imported from out-of-compact states (Herness, 2013). Thus, all 65 operating commercial NPPs have access to a disposal facility for their Class A LLRW spent IERs, and potentially have access to a disposal facility for their Class B and C LLRW spent IERs at this time. Note, however, that the scope of the evaluation presented in this report was defined by the Commission at an earlier time when the majority of NPPs had no access, or limited access, to Class B and C disposal.

NPPs and LLRW processing and disposal companies are exploring alternatives for managing Class B and C concentration spent IERs from NPPs. 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 volume-reduce the Class B and C concentration spent IERs 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.

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

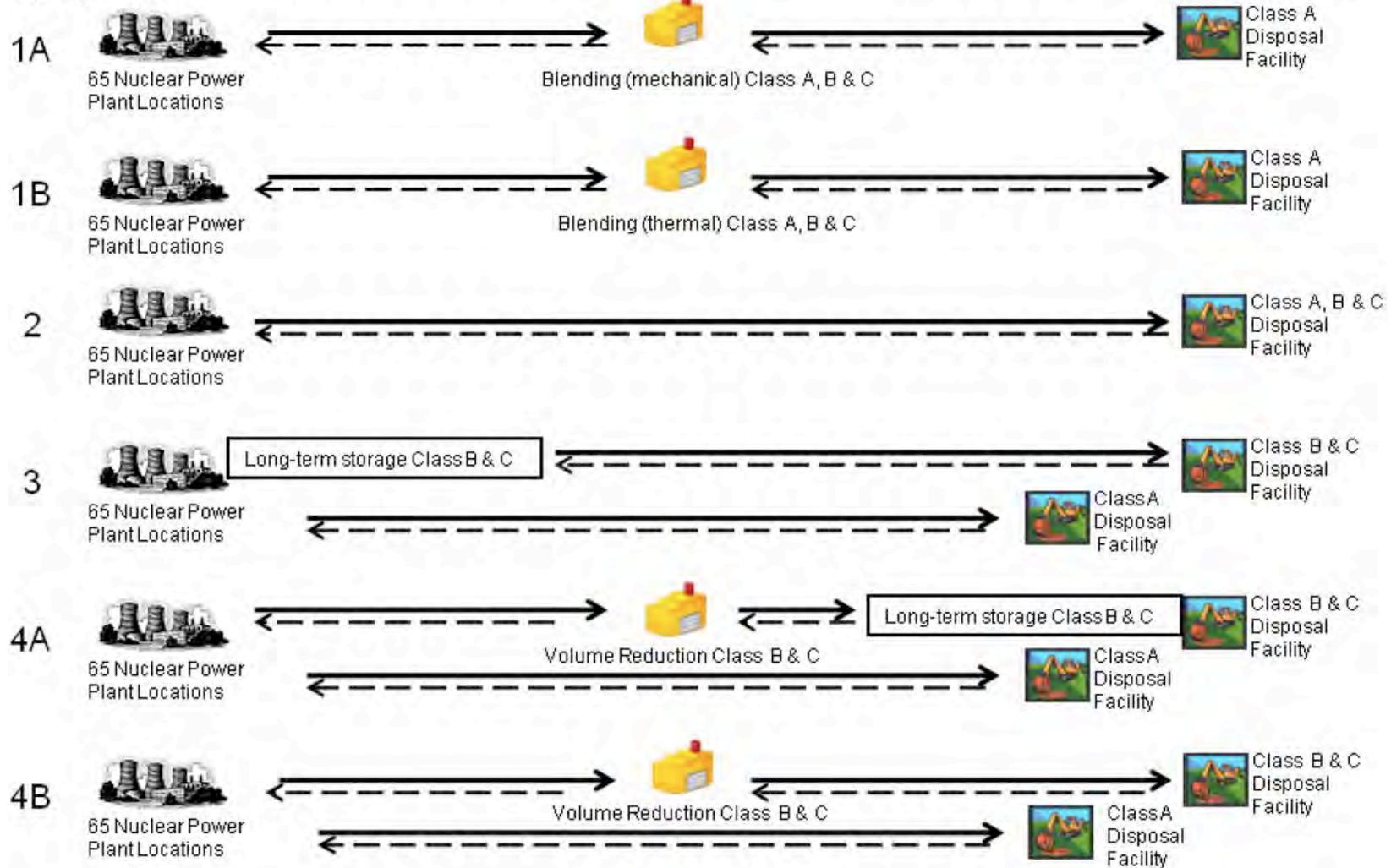
The six alternatives for handling LLRW spent IERs from commercial NPPs are listed and briefly described below. Figure 2 graphically presents these alternatives. As discussed in Section 1, these six alternatives are adapted from, and are consistent with, the four basic alternatives defined for evaluation 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:

- 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 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.

## Alternative



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 an average volume reduction of 5 to 1 of the Class B and C concentration spent IERs (Lowman, 2011), and that the volume reduction facility would control the process to ensure that the final waste forms do not exceed Class C limits. 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.<sup>13</sup> 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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<sup>13</sup> 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.<sup>14</sup>
- 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.<sup>15</sup>
- 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.
- Sufficient numbers of Type A and Type B shipping casks are available to implement each of the alternatives.

The above seven 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

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<sup>14</sup> 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.

<sup>15</sup> 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 and of returned empty casks could be by some mode other than by truck (e.g., by rail); and (4) there may be insufficient Type A and Type B shipping casks available to transport all spent IERs generated annually. Thus, the actual impacts of the alternatives, if implemented, would be of lesser magnitude because, for example, the environmental impacts would be divided among more than one alternative, or there could be fewer possible annual shipments of untreated and treated spent IERs.

### **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 (i.e., NPPs and spent IER storage, processing, and disposal facilities) 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 conducting this evaluation. The assumptions and conditions 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 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 in this report because there is no basis for determining the past, present, and reasonably foreseeable future actions on which such an analysis could be based.

### **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:

- Accidents and Other Off-Normal Conditions. 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 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 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 a LLRW disposal facility (Alternatives 2 and 3). Offsite transport from a waste processing facility would be to a 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

Because of the radioactivity levels of the spent IERs, HICs or liners containing these materials are placed and transported in special transportation containers. As discussed in Section 2.1.2, the type of shipping container, or cask, used depends on a number of factors, including the mix of radionuclides in the material to be transported and the specific activity of the material. Spent IERs with certain limited specific activities can be shipped as Low Specific Activity (LSA) material.<sup>16</sup> The NRC radioactive material packaging and transportation regulations in 10 CFR Part 71 set the boundary for LSA material. Spent IERs that have a specific activity greater than the LSA limit are shipped in shielded Type A or Type B certified shipping casks (shown in Figure 3 and Figure 4, respectively), depending on the  $A_2$  value<sup>17</sup> of the material being shipped (10 CFR Part 71, Appendix A). Spent IERs that exceed the  $A_2$  value are shipped in Type B shipping casks, which are more robust than Type A casks. If the specific activity of the spent IERs exceeds the LSA limit, and if the total 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 the LSA limit, the  $A_2$  limit, and 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,



**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

<sup>16</sup> Low Specific Activity (LSA) material means radioactive material with limited specific activity that is nonfissile or is excepted under 10 CFR 71.15, and satisfies the descriptions and limits for LSA-I, LSA-II, and LSA-III materials set forth in 10 CFR 71.4. Shielding materials surrounding the LSA material may not be considered in determining the estimated average specific activity of the package contents. (10 CFR 71.4)

<sup>17</sup> 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 complete definitions of LSA and SCO materials in 10 CFR 71.4.)

Section A.2.2. For reasons detailed in Section A.2.2, this evaluation assumes that all the spent IERs are shipped in Type A or Type B shielded casks.

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 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.

#### **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 as 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 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.



**Figure 5 Low-Level Radioactive Waste Disposal Vaults in a Disposal Trench**

Source: SC DHEC, 2007

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°C (1,472°F)) steam would be introduced into the bottom of the pyrolyzer and 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<sub>2</sub>), 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<sub>2</sub> 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<sub>2</sub> 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 (e.g., ceramic filters, HEPA filters, and contaminated salt wastes) are relatively small in volume when compared to the volume of materials processed, and contain less than one-half of one percent of the incoming radioactivity (Mason et al., 1999; THOR<sup>sm</sup>, 2006). The thermal process produces no liquid releases and no secondary solid wastes, except the mercury adsorber media (THOR<sup>sm</sup>, 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<sup>sm</sup>, 2006) when operating, and this use would equate to slightly more than 1 million gallons per year, which would not be unusual for a small 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<sup>3</sup> and 3.7 m<sup>3</sup>, 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<sup>3</sup> (112 ft<sup>3</sup>) and a diameter of 1.55 m (5.08 ft) (see Table A-1 in Appendix A).<sup>18</sup> Therefore, the average BWR unit would produce 24 liners of Class B and C concentration spent IERs over 20 years (3.7 m<sup>3</sup> of spent IERs per year ÷ 3.17 m<sup>3</sup> 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

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<sup>18</sup> The model L8-120 liner is used for illustrative purposes in the evaluation. Other liner types are available for use for containing spent IERs.

((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 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<sup>2</sup> (360 ft<sup>2</sup>). 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<sup>2</sup> (about 15,500 ft<sup>2</sup>), 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<sup>2</sup> (15,500-ft<sup>2</sup>) 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 (IAEA, 2002a), 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. An average volume reduction of five to one in the treatment process is assumed (Lowman, 2011), and the volume reduction facility would control the process to ensure that the final waste forms do not exceed Class C limits. 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 ( $353 \text{ m}^3$  of Class B and C concentration spent IERs per year (from Table 2)  $\div$   $3.17 \text{ m}^3$  of spent IERs per liner  $\times$  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 ( $2227 \text{ containers} \div 5 \approx 446 \text{ containers}$ ). Based on the estimated  $33.6 \text{ m}^2$  ( $360 \text{ ft}^2$ ) 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  $16,500 \text{ m}^2$  (about  $177,000 \text{ ft}^2$ ), 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),<sup>19</sup> the storage facility would occupy less than 1 percent of the total site area.

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<sup>19</sup> For example, the recently licensed LLRW disposal facility near Andrews, Texas, occupies an area of about 542 hectares (1338 acres) (Waste Control Specialists, 2011).

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 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 <sup>a</sup>				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

<sup>a</sup> 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)).<sup>20</sup> 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<sub>10</sub>), sulfur dioxide (SO<sub>2</sub>), carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), 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,

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<sup>20</sup> 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 3.11 mSv (311 mrem) (NCRP, 2009).

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 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) stormwater requirements and 10 CFR 20.1301 dose-based 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<sup>21</sup> 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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<sup>21</sup> 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  $1.13 \times 10^{10}$  metric tons per year ( $1.25 \times 10^{10}$  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<sup>22</sup>), 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<sup>23</sup> 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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<sup>22</sup> 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.

<sup>23</sup> 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, from natural sources, of 3.11 mSv/year (311 mrem/year) (NCRP, 2009), as a percentage of this background dose. For populations, the annual collective dose<sup>24</sup> is compared to 3.11 mSv/year (311 mrem/year) multiplied by the affected population, since each member of the population sustains this annual average background dose. The use of the annual average U.S. natural 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,  $6 \times 10^{-5}$  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).<sup>25</sup>

### **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<sup>26</sup>

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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<sup>24</sup> See Section A.3.2.2 for definition of collective dose.

<sup>25</sup> 2010 total estimated cancer fatalities in the U.S. derived by the American Cancer Society from U.S. mortality data, 1969-2007.

<sup>26</sup> 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<sup>27</sup>, and (2) the doses from exposures to multiple shipments are additive<sup>28</sup>. 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 GEORGAPHIC 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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<sup>27</sup> 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.

<sup>28</sup> 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 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). 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 be exposed to the actual radionuclide inventory.<sup>29</sup> 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 that can be transported in a Type A cask cannot 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 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

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<sup>29</sup> Radionuclide inventory is the list of radionuclides in a particular material and the activity of each, expressed in curies.

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.<sup>30</sup> 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<sup>31</sup>, 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 the highest release fraction of the six and, therefore, would yield the most conservative impact analysis results.

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<sup>30</sup> 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).

<sup>31</sup> Release fraction is the fraction of total radioactivity in the cask released for a particular accident scenario.

#### **5.1.2.8 Waste Management**

Waste management impacts 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, a subpart of the full evaluation, 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 could result from reduction in 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 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
<b>Air Quality</b>	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
<b>Ecological Resources</b>	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
<b>Historic and Cultural Resources</b>	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
<b>Noise</b>	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
<b>Public and Occupational Health</b>	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
<b>Soil</b>	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
<b>Transportation</b>	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
<b>Waste Management</b>	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
<b>Water Resources</b>	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 <sup>a</sup>					
	<b>ALTERNATIVE 1A</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b>ALTERNATIVE 1B</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b>ALTERNATIVE 2</b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b>ALTERNATIVE 3</b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4A</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4B</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b>AIR QUALITY:</b> <i>Radiological</i>	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 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 <sup>a</sup>					
	<b>ALTERNATIVE 1A</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b>ALTERNATIVE 1B</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b>ALTERNATIVE 2</b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b>ALTERNATIVE 3</b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4A</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4B</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b>AIR QUALITY: Radiological (Cont.)</b>	processing alternatives (1B, 4A, and 4B) that involve heating of the spent IERs and resulting increased volatilization.					
<b>AIR QUALITY: Non-radiological</b> <i>(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.)</i>	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 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 <sup>a</sup>					
	<b>ALTERNATIVE 1A</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b>ALTERNATIVE 1B</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b>ALTERNATIVE 2</b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b>ALTERNATIVE 3</b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4A</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4B</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b>AIR QUALITY: Non-radiological (Cont.)</b>	<p>(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.</p> <p>Best management practices (BMPs) would be employed to minimize fugitive dust generation during spent IER disposal operations at the LLRW disposal facility.</p>	<p>employed at the thermal processing facility to control air emissions, and stack emissions must comply with NAAQS, NESHAPs, and other permit or license requirements.</p>		<p>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.</p>	<p>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.</p>	

**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 <sup>a</sup>					
	<b>ALTERNATIVE 1A</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b>ALTERNATIVE 1B</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b>ALTERNATIVE 2</b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b>ALTERNATIVE 3</b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4A</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4B</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b>AIR QUALITY:</b> <i>Non-radiological (Cont.)</i>				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.	
<b>ECOLOGICAL RESOURCES</b>	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 <sup>a</sup>					
	<b><u>ALTERNATIVE 1A</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b><u>ALTERNATIVE 1B</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b><u>ALTERNATIVE 2</u></b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b><u>ALTERNATIVE 3</u></b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4A</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4B</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b><u>ECOLOGICAL RESOURCES</u></b> (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 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 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.	
<b><u>HISTORIC AND CULTURAL RESOURCES</u></b>	SMALL. The existing NPPs and mechanical mixing (blending) and disposal facilities would be operating within existing facility footprints. There would be minimal or no additional ground	SMALL. Impacts to historic and cultural resources from spent IER handling, thermal processing (blending), transport, and disposal activities	SMALL. Impacts to historic and cultural resources from spent IER handling, transport, and disposal activities would be similar to those described for	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 to those described for	SMALL. Impacts to historic and cultural resources from spent IER handling, thermal processing (volume reduction), transport, and disposal activities would be similar to

**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 <sup>a</sup>					
	<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 <sup>b</sup>	<u>ALTERNATIVE 4A</u> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<u>ALTERNATIVE 4B</u> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<u>HISTORIC AND CULTURAL RESOURCES</u> (Cont.)	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.	would be similar to those described for Alternative 1A.	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 <i>National Register of Historic Places</i> (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 historic and cultural resources would be	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 storage facility.	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 <sup>a</sup>					
	<b><u>ALTERNATIVE 1A</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b><u>ALTERNATIVE 1B</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b><u>ALTERNATIVE 2</u></b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b><u>ALTERNATIVE 3</u></b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4A</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4B</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b><u>HISTORIC AND CULTURAL RESOURCES</u></b> (Cont.)				expected during operation of the long-term spent IER storage facilities.		
<b><u>NOISE</u></b> (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.

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**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 <sup>a</sup>					
	<b><u>ALTERNATIVE 1A</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b><u>ALTERNATIVE 1B</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b><u>ALTERNATIVE 2</u></b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b><u>ALTERNATIVE 3</u></b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4A</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4B</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b><u>PUBLIC AND OCCUPATIONAL HEALTH:</u></b> <i>Occupational Health – Radiological</i>	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 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 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 used during construction.	SMALL. Radiological impacts to workers performing spent IER handling, transport, thermal processing (volume reduction), long-term storage, and disposal activities could be 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 <sup>a</sup>					
	<b><u>ALTERNATIVE 1A</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b><u>ALTERNATIVE 1B</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b><u>ALTERNATIVE 2</u></b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b><u>ALTERNATIVE 3</u></b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4A</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4B</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b><u>PUBLIC AND OCCUPATIONAL HEALTH:</u></b> <i>Occupational Health – Radiological (Cont.)</i>	in adherence to the above stated requirements, practices, and procedures.					
<b><u>PUBLIC AND OCCUPATIONAL HEALTH:</u></b> <i>Occupational Health – Non-radiological</i>	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 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	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 <sup>a</sup>					
	<b>ALTERNATIVE 1A</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b>ALTERNATIVE 1B</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b>ALTERNATIVE 2</b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b>ALTERNATIVE 3</b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4A</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4B</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b>PUBLIC AND OCCUPATIONAL HEALTH:</b> <i>Occupational Health – Non-radiological (Cont.)</i>				spent IER storage facilities would be expected to be minimal.	workers during maintenance and monitoring of the long-term spent IER storage facility would be expected to be minimal.	
<b>PUBLIC AND OCCUPATIONAL HEALTH:</b> <i>Public Health – Radiological</i>  <i>(NOTE: Radiological impacts to public health from incident-free transportation and transportation accidents are described later in this table under Transportation.)</i>	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	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	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	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.

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**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 <sup>a</sup>					
	<b><u>ALTERNATIVE 1A</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b><u>ALTERNATIVE 1B</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b><u>ALTERNATIVE 2</u></b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b><u>ALTERNATIVE 3</u></b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4A</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4B</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b><u>PUBLIC AND OCCUPATIONAL HEALTH:</u></b> <i>Public Health – Radiological (Cont.)</i>	and for waste management, thus minimizing potential impacts to the public (see under Air Quality (Radiological), Waste Management, and Water Resources (Water Quality) in this table).			materials would be used during construction. Long-term storage of spent IERs is not anticipated to result in public health impacts due to the implementation of maintenance and monitoring programs.	to the implementation of maintenance and monitoring programs.	
<b><u>PUBLIC AND OCCUPATIONAL HEALTH:</u></b> <i>Public Health – Non-radiological (NOTE: Non-radiological impacts to public health from transportation accidents are described later in this table under Transportation.)</i>	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,	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	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	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 <sup>a</sup>					
	<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 <sup>b</sup>	<u>ALTERNATIVE 4A</u> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<u>ALTERNATIVE 4B</u> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<u>PUBLIC AND OCCUPATIONAL HEALTH:</u> <i>Public Health – Non-radiological (Cont.)</i>	and local regulations for air quality, noise, and 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.			of spent IERs at the NPPs is not anticipated to result in public health impacts due to the implementation of maintenance and monitoring programs.	not anticipated to result in public health impacts due to the implementation of maintenance and monitoring programs.	
<u>SOIL</u>	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	SMALL. Soil impacts as a result of spent IER handling, transport, and disposal activities would be similar to those	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	SMALL. Soil impacts as a result of spent IER handling, transport, thermal processing (volume reduction), and disposal activities would be similar to those described	SMALL. Soil impacts as a result of spent IER handling, transport, thermal processing (volume reduction), and disposal activities would be similar to those

**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 <sup>a</sup>					
	<b>ALTERNATIVE 1A</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b>ALTERNATIVE 1B</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b>ALTERNATIVE 2</b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b>ALTERNATIVE 3</b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4A</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4B</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b>SOIL</b> <i>(Cont.)</i>	<p>minor accidental spills that would be immediately addressed in accordance with spill prevention, control, and counter-measures (SPCC) plans.</p> <p>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.</p>	would be similar to those described for Alternative 1A.	described for Alternative 1A. This alternative involves no waste processing and associated soil impacts, if any.	<p>alternative involves no waste processing and associated soil impacts.</p> <p>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.</p>	<p>for Alternative 1A.</p> <p>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.</p>	described for Alternative 1A.
<b>TRANSPORTATION:</b> <i>Local and National Traffic<sup>c</sup></i>	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	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	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	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	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	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 <sup>a</sup>					
	<b><u>ALTERNATIVE 1A</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b><u>ALTERNATIVE 1B</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b><u>ALTERNATIVE 2</u></b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b><u>ALTERNATIVE 3</u></b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4A</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4B</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b><u>TRANSPORTATION:</u></b> <i>Local and National Traffic (Cont.)</i>	<p>additions to local traffic near industrial and waste disposal sites.</p> <p>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.</p> <p>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</p>	<p>would be the same. Therefore, impacts on local and national traffic would be similar to those described for Alternative 1A.</p>	<p>vicinity of a waste disposal site.</p> <p>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.</p> <p>Corresponding small local and national impacts on traffic congestion, air quality, noise levels, and road surface wear would be as described under Alternative 1A.</p>	<p>Years 1-20, total annual 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.</p> <p>Corresponding small local and national impacts on traffic congestion, air quality, noise levels, and road surface wear would be as described under Alternative 1A.</p>	<p>additions to local traffic near industrial and waste disposal sites.</p> <p>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.</p> <p>Corresponding small local and national impacts on traffic congestion, air quality, noise levels, and road surface wear would be as described under Alternative 1A.</p>	

**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 <sup>a</sup>					
	<b>ALTERNATIVE 1A</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b>ALTERNATIVE 1B</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b>ALTERNATIVE 2</b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b>ALTERNATIVE 3</b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4A</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4B</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b>TRANSPORTATION: Local and National Traffic (Cont.)</b>	intermittent nature of these operations, which would be dispersed over wide geographic areas.					
<b>TRANSPORTATION: Routine (Incident-free) - Radiological (Individuals and Populations)<sup>f</sup></b> <i>(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.)</i>	SMALL. For individuals, the maximally exposed individual (MEI) dose from moving trucks carrying all spent IER shipments annually would be approximately 0.08% of the average annual U.S. background radiation dose, and the corresponding LCF would be negligible at $3 \times 10^{-11}$ % 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 0.14% of the background dose, and the corresponding LCF would be $5 \times 10^{-11}$ % of 2010 estimated cancer fatalities. Radiation doses and LCFs to all other individual	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 $1 \times 10^{-11}$ % 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 $1 \times 10^{-11}$ % 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 0.058% of the background dose, and the corresponding LCF would be $2 \times 10^{-11}$ % 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 $1 \times 10^{-11}$ % 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 0.077% of the background dose, and the corresponding LCF would be $3 \times 10^{-11}$ % 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.

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**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 <sup>a</sup>					
	<b>ALTERNATIVE 1A</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b>ALTERNATIVE 1B</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b>ALTERNATIVE 2</b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b>ALTERNATIVE 3</b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4A</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4B</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b>TRANSPORTATION: Routine (Incident-free) - Radiological (Individuals and Populations) (Cont.)</b>	<p>receptors would be orders of magnitude lower.</p> <p>For populations along the <u>representative transportation routes</u>, the maximum annual collective population dose and LCF from moving trucks, from all annual spent IER shipments, would be about <math>5 \times 10^{-6}</math>% of the U.S. average annual background radiation dose and <math>3 \times 10^{-9}</math>% of 2010 total estimated U.S. cancer fatalities, respectively.</p> <p>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 maximum LCFs as</p>		<p>0.074% of the background dose, and the corresponding LCF would be <math>2 \times 10^{-11}</math>% of 2010 estimated cancer fatalities. Radiation doses and LCFs to all other individual receptors would be orders of magnitude lower.</p> <p>For populations along the <u>representative transportation routes</u>, the maximum annual collective population dose and LCF from moving trucks, from all annual spent IER shipments, would be about <math>10^{-4}</math>% of the U.S. average annual background radiation dose and <math>2 \times 10^{-9}</math>% of 2010 total estimated U.S.</p>	<p>be orders of magnitude lower.</p> <p>For populations along the <u>representative transportation routes</u>, in Years 1-20, the maximum annual collective population dose and LCF from moving trucks, from all annual spent IER shipments, would be about <math>8 \times 10^{-5}</math>% of the U.S. average annual background radiation dose and <math>1 \times 10^{-9}</math>% of 2010 total estimated U.S. cancer fatalities, respectively.</p> <p>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 maximum LCFs as percentages of</p>	<p>lower.</p> <p>For populations along the <u>representative transportation routes</u>, the maximum annual collective population dose and LCF from moving trucks, from all annual spent IER shipments, would be about <math>8 \times 10^{-5}</math>% of the U.S. average annual background radiation dose and <math>4 \times 10^{-10}</math>% of 2010 total estimated U.S. cancer fatalities, respectively.</p> <p>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</p>	

**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 <sup>a</sup>					
	<b><u>ALTERNATIVE 1A</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b><u>ALTERNATIVE 1B</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b><u>ALTERNATIVE 2</u></b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b><u>ALTERNATIVE 3</u></b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4A</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4B</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b><u>TRANSPORTATION: Routine (Incident-free) - Radiological (Individuals and Populations) (Cont.)</u></b>	percentages of 2010 total estimated U.S. cancer fatalities would be negligible at about $2 \times 10^{-9}\%$ and $4 \times 10^{-8}\%$ , respectively.		cancer fatalities, respectively.  <u>For residents near rural and suburban truck rest and refueling stops</u> , 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 $8 \times 10^{-10}\%$ and $2 \times 10^{-8}\%$ , respectively.	2010 total estimated U.S. cancer fatalities would be negligible at about $7 \times 10^{-10}\%$ and $2 \times 10^{-8}\%$ , 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 $9 \times 10^{-10}\%$ and $2 \times 10^{-8}\%$ , respectively.	
<b><u>TRANSPORTATION: Accidents – Non-radiological and Radiological</u></b>	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	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 <sup>a</sup>					
	<b><u>ALTERNATIVE 1A</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b><u>ALTERNATIVE 1B</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b><u>ALTERNATIVE 2</u></b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b><u>ALTERNATIVE 3</u></b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4A</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4B</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b><u>TRANSPORTATION: Accidents – Non-radiological and Radiological (Cont.)</u></b>	<p>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.</p> <p><u>Regarding radiological impacts of transportation accidents in which no radioactive materials are released</u>, 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 annual traffic fatalities</p>	<p>similar to those described for Alternative 1A.</p>	<p>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.</p> <p><u>Regarding radiological impacts of transportation accidents in which no radioactive materials are released</u>, in the</p>	<p>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.</p> <p><u>Regarding radiological impacts of transportation accidents in which no radioactive materials are released</u>, 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 0.005%, and the corresponding LCF as a percentage of estimated annual traffic fatalities involving spent IER</p>	<p>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.</p> <p><u>Regarding radiological impacts of transportation accidents in which no radioactive materials are released</u>, in the most conservative case evaluated, the collective population dose as a percentage of U.S. average annual background dose would be 0.006%, and the corresponding LCF as a percentage of estimated annual traffic fatalities involving spent IER</p>	<p>similar to those described for Alternative 4A.</p>

**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 <sup>a</sup>					
	<b><u>ALTERNATIVE 1A</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b><u>ALTERNATIVE 1B</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b><u>ALTERNATIVE 2</u></b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b><u>ALTERNATIVE 3</u></b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4A</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4B</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b><u>TRANSPORTATION: Accidents – Non-radiological and Radiological (Cont.)</u></b>	<p>involving spent IER shipments and of 2010 estimated U.S. cancer fatalities would be 0.136% and <math>2.5 \times 10^{-9}\%</math>, respectively. For the nearest member of the public, the MEI, the dose and LCF are 0.013% of background and <math>2.3 \times 10^{-8}\%</math> of 2010 total estimated U.S. cancer fatalities, respectively.</p> <p><u>Regarding radiological impacts of transportation accidents in which radioactive materials could be released from Type A and Type B casks,</u> 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 and LCF as percentages of</p>		<p>most conservative case evaluated, the collective population dose as a percentage of U.S. average annual background dose would be 0.006%, 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 <math>7.7 \times 10^{-9}\%</math>, respectively. The potential radiological impact to the MEI would be the same as described under Alternative 1A.</p> <p><u>Regarding radiological impacts of transportation accidents in which</u></p>	<p>shipments and of 2010 estimated U.S. cancer fatalities would be 0.078% and <math>1.2 \times 10^{-9}\%</math>, respectively. The potential radiological impact to the MEI would be the same as described under Alternative 1A.</p> <p><u>Regarding radiological impacts of transportation accidents in which radioactive materials could be released from Type A and Type B casks,</u> see discussion under Alternative 1A.</p> <p>Non-radiological and radiological impacts from transportation accidents after Year 21 would be similar to those described for Alternative 2.</p>	<p>shipments and of 2010 estimated U.S. cancer fatalities would be 0.078% and <math>1.2 \times 10^{-9}\%</math>, respectively. The potential radiological impact to the MEI would be the same as described under Alternative 1A.</p> <p><u>Regarding radiological impacts of transportation accidents in which radioactive materials could be released from Type A and Type B casks,</u> see discussion under Alternative 1A.</p>	

**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 <sup>a</sup>					
	<b>ALTERNATIVE 1A</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b>ALTERNATIVE 1B</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b>ALTERNATIVE 2</b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b>ALTERNATIVE 3</b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4A</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4B</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b>TRANSPORTATION: Accidents – Non-radiological and Radiological (Cont.)</b>	U.S. average annual background and 2010 U.S. total estimated cancer fatalities would be 36% and $1 \times 10^{-8}\%$ , 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 19% and $6 \times 10^{-9}\%$ , respectively; and the corresponding collective dose and LCF percentages would be 0.25% and $2 \times 10^{-7}\%$ , respectively.		<u>radioactive materials could be released from Type A and Type B casks</u> , see discussion under Alternative 1A.			
<b>WASTE MANAGEMENT</b>	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 the nature of these activities. Thus, there	SMALL. Waste management impacts resulting from spent IER handling, transport, and disposal activities would be similar to those described for Alternative 1A. Small quantities of LLRW and	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	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 generated under this alternative.	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 thermal processing technologies, and all other	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 alternatives use similar thermal processing

**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 <sup>a</sup>					
	<b><u>ALTERNATIVE 1A</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b><u>ALTERNATIVE 1B</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b><u>ALTERNATIVE 2</u></b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b><u>ALTERNATIVE 3</u></b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4A</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4B</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b><u>WASTE MANAGEMENT</u></b> <i>(Cont.)</i>	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 and 10 CFR 20.1301 dose-based requirements).	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 and 10 CFR 20.1301 dose-based requirements).	incidental to spent IER processing would be 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 permitted limits (e.g., under NPDES requirements and 10 CFR 20.1301 dose-	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 regulations, including discharging within	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 <sup>a</sup>					
	<b>ALTERNATIVE 1A</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b>ALTERNATIVE 1B</b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b>ALTERNATIVE 2</b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b>ALTERNATIVE 3</b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4A</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b>ALTERNATIVE 4B</b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b>WASTE MANAGEMENT</b> <i>(Cont.)</i>				based requirements).	permitted limits (e.g., under NPDES requirements and 10 CFR 20.1301 dose-based requirements).	
<b>WATER RESOURCES:</b> <i>Water Quality</i>	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 and 10 CFR 20.1301 dose-based requirements) requirements that are protective of human health and the environment, thereby limiting any impacts to surface water and groundwater. Accidental spills would be addressed in accordance	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 effluent discharge is	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.

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**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 <sup>a</sup>					
	<b><u>ALTERNATIVE 1A</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING MECHANICAL MIXING)	<b><u>ALTERNATIVE 1B</u></b> DISPOSAL OF BLENDED CLASS A, B, AND C SPENT IER LLRW FROM A CENTRAL PROCESSING FACILITY (USING THERMAL PROCESSING)	<b><u>ALTERNATIVE 2</u></b> DIRECT DISPOSAL OF CLASS A, B, AND C SPENT IER LLRW	<b><u>ALTERNATIVE 3</u></b> LONG-TERM ONSITE STORAGE OF CLASS B AND C CONCENTRATION SPENT IERs, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4A</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<b><u>ALTERNATIVE 4B</u></b> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<b><u>WATER RESOURCES:</u></b> <i>Water Quality (Cont.)</i>	with SPCC plans.			anticipated from long-term spent IER storage.		
<b><u>WATER RESOURCES:</u></b> <i>Water Supply</i>	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	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	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.

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**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 <sup>a</sup>					
	<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 <sup>b</sup>	<u>ALTERNATIVE 4A</u> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, LONG-TERM STORAGE, THEN DISPOSAL <sup>b</sup>	<u>ALTERNATIVE 4B</u> VOLUME REDUCTION OF CLASS B AND C CONCENTRATION SPENT IERs AT A PROCESSING FACILITY, THEN DISPOSAL <sup>b</sup>
<u>WATER RESOURCES:</u> <i>Water Supply (Cont.)</i>				the long-term storage of spent IERs.	expected to result in impacts to water supply. There would be minimal water use associated with the long-term storage of spent IERs.	

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<sup>a</sup> 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.

<sup>b</sup> Alternative 3 includes immediate disposal of Class A LLRW spent IERs.

<sup>c</sup> 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, dose-based requirements under 10 CFR 20.1301), 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 0.08 percent of the average annual U.S. background radiation dose; and the corresponding LCFs would be negligible, ranging from about  $1 \times 10^{-11}$  to  $3 \times 10^{-11}$  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 0.058 to 0.14 percent of the background dose, and the corresponding LCFs would range from  $2 \times 10^{-11}$  to  $5 \times 10^{-11}$  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  $5 \times 10^{-5}$  to  $10^{-4}$  percent of the U.S. average annual background radiation dose; and corresponding LCFs would be negligible, ranging from about  $1 \times 10^{-10}$  to  $3 \times 10^{-9}$  percent of 2010 total estimated U.S. cancer fatalities, respectively. For trucks at rural and suburban rest and refueling stops, maximum annual collective population doses from stationary trucks would range from about 0.1 to 0.2 percent of background; and corresponding LCFs would be negligible, ranging from about  $1 \times 10^{-8}$  to  $4 \times 10^{-8}$  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  $7.7 \times 10^{-9}$  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 36 percent and  $1 \times 10^{-8}$  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 19 percent and  $6 \times 10^{-9}$  percent, respectively; and the corresponding collective dose and LCF percentages would be 0.25 percent and  $2 \times 10^{-7}$  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 and dose-based requirements under 10 CFR 20.1301).

### **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<sup>1</sup> 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 waste disposal facilities are considered in the analysis. Routine transportation of radioactive materials could also affect air quality, noise, and road surface wear.

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<sup>1</sup> 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.

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<sup>2</sup> 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.
- 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

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<sup>2</sup> 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 3.11 mSv (311 mrem) (NCRP, 2009).

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 environment 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.<sup>3</sup>

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<sup>3</sup> 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.

### **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, prior to shipping, spent IERs are placed in High Integrity Containers (HICs) or liners at the NPPs. As discussed in Section 4.1.2.1, the spent IERs are generally sufficiently radioactive that they must be transported in special transportation containers when shipped on public roads. The HICs or liners are placed in these special transportation containers for offsite shipment. The type of shipping container that is used depends on a number of factors, including the mix of radionuclides in the material, the specific activity mix of radionuclides, and the unshielded dose rate from the HIC or liner.

“Low specific activity” spent IERs may be shipped as NRC-defined Low Specific Activity (LSA) material<sup>4</sup> in industrial packages (shipping containers) that are not certified by the NRC

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<sup>4</sup> Low Specific Activity (LSA) material means radioactive material with limited specific activity which is nonfissile or is excepted under 10 CFR 71.15, and which satisfies the descriptions and limits for LSA-I, LSA-II, and LSA-III materials set forth in 10 CFR 71.4. Shielding materials surrounding the LSA material may not be considered in determining the estimated average specific activity of the package contents. (10 CFR 71.4)

(i.e., packages that are exempt from NRC certification), if the specific activity (the activity per unit mass) of the spent IERs is low enough and other requirements are met. The following three criteria must be met for shipping spent IERs as LSA material (specifically LSA-II):

- Average specific activity does not exceed one-ten thousandth of the  $A_2$  value<sup>5</sup> per gram of material (10 CFR 71.4)<sup>6</sup>;
- External radiation from the shipping package must not exceed 0.1 millisievert (mSv)/hour (10 millirem (mrem)/hour) at 2 meters (m) (6.6 feet (ft)) (10 CFR 71.47(b)(3)); and
- The material must have an external radiation dose less than or equal to 10 mSv/hour (1 rem/hour) at a distance of 3 m (10 ft) from the unshielded material (10 CFR 71.14(b)(3)(i)).

Spent IERs that cannot be shipped as LSA material would be shipped in either a Type A or Type B shielded and certified shipping cask, depending on the  $A_2$  value 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. (See Table A-18 in Section A.3.3.2.2 later in this appendix for the calculation of the  $A_2$  value for typical spent IER shipments.)

Note that there could be special cases resulting from the NRC regulations discussed above for shipments of materials (e.g., spent IERs) that meet the definition of LSA, two such cases are listed below:

- A package of spent IERs that meets the LSA criteria, and can be shipped as LSA, could contain more than the  $A_2$  value as long as the LSA criteria of 10 CFR Part 71 are met.
- Low specific activity material (i.e., material that has a specific activity less than or equal to one-ten thousandth of the  $A_2$  value per gram) would be shipped in a Type A cask if the external dose rate from the package is too high and the package requires the shielding that the Type A cask provides.

Although some spent IERs may be shipped as LSA in industrial packages, this evaluation assumes that all the spent IERs are shipped in Type A and Type B casks. The Type A and Type B casks that are typically used for shipping spent IERs from commercial NPPs are the Chem-Nuclear Systems (CNS) 14-215 and the CNS 8-120B, respectively. Table A-1 summarizes the specifications (capacities, dimensions, and loaded weights) of these two

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<sup>5</sup> 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 complete definitions of LSA and SCO materials in 10 CFR 71.4.)

<sup>6</sup> For LSA-II material.

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 <sup>a</sup> (CNS 14-215)	TYPE B CASK <sup>b</sup> (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 <sup>c</sup> ) (m <sup>3</sup> (ft <sup>3</sup> ))	5.29 (187)	3.17 (112)
Total Length of Cask (m (ft)) <sup>d</sup>	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)

<sup>a</sup> Source: EnergySolutions, 2010b.

<sup>b</sup> Source: EnergySolutions, 2010a.

<sup>c</sup> 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.

<sup>d</sup> m = meters; ft = feet.

The assumption that all the spent IERs are shipped in Type A or Type B casks results in a more conservative analysis than assuming that some spent IERs are shipped as LSA in industrial packages. This assertion is directly tied to four primary factors detailed in this appendix upon which potential environmental impacts of transporting spent IERs are based: (1) the total number of shipments (affects local and national traffic); (2) the radiation dose rate from the shipping container (affects radiation doses to members of the public from routine, incident-free transport); (3) the number of miles driven (affects the potential number of transportation accidents); and (4) the dose rate from unshielded material (affects the potential impacts from an accident in which the radioactive contents of a shipping container are released). Each factor is discussed below, to establish why the assumed use of only Type A and Type B casks for spent IER shipments is more conservative than using industrial packages for some shipments:

1. Total number of shipments: Because Type A and Type B packages incorporate heavy shielding and Type B packages also have impact load limiters, the weight of Type A and B casks is higher than for industrial packages; and while more than one industrial package would be transported per truck shipment to optimize shipping, only one Type A or Type B cask can be transported per truck. Thus assuming the use of only Type A and B packages for spent IER transport results in the estimation of more shipments and, therefore, greater potential impacts on local and national traffic, than would be estimated when using smaller, lighter industrial packages for some shipments.
2. Dose rate from the shipping container: By regulation, the maximum allowable dose rate on the outside of the shipping container is the same for LSA, Type A, and Type B packages (i.e. 0.1 mSv/hour (10 mrem/hour) at 2 m (10 CFR 71.47(b)(3))). Because the

external package dose limit is the same for all three package types (i.e., LSA = Type A = Type B), and there will be more shipments if using only Type A and Type B casks (see above), the estimated population dose is increased by the assumption that all shipments are in Type A and Type B casks.

3. Number of miles driven: Since assuming the use of only Type A and B packages results in the estimation of more shipments and, therefore, more miles driven than would be estimated when using industrial packages for some shipments, it follows that the more miles that are driven, the more potential transportation accidents could occur.
4. Dose rate from unshielded material: In Section A.3.3.2.2, the dose to the maximally exposed member of the public is calculated, based on an accident that releases the entire  $A_2$  quantity of spent IERs from a Type A cask. In this accident scenario, the estimated dose to the member of the public of 1.11 mSv (111 mrem) is based on a 10 hour exposure, at 30 m, to an unshielded  $A_2$  quantity of spent IERs (see Table A-19). If instead of a Type A cask with an  $A_2$  quantity, the contents of an industrial package, carrying spent IERs as LSA-II were released, the dose to a member of the public would be lower, at 1 mSv (100 mrem).<sup>7</sup>

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 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<sup>3</sup> (90,620 ft<sup>3</sup>)) 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

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<sup>7</sup> This dose to a member of the public is based on the following: The regulatory maximum dose rate for unshielded LSA is 10 mSv/hour @ 3 m (10 CFR 71.14(b)(3)(i)). Thus 10 hours of exposure at 3 m gives a dose of 100 mSv at 3 m. Then to calculate what this dose of 100 mSv at 3 m would be at 30 m, since dose is inversely proportional to the square of the distance from the source, 100 mSv is multiplied by the ratio of squares of the distances (3 m and 30 m). The dose for 10 hours of exposure @ 30 m =  $[(3 \times 3) / (30 \times 30)] \times 100 \text{ mSv} = 1 \text{ mSv}$ .

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<sup>8</sup> 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 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.,  $2215 \text{ m}^3/\text{year (Class A)} \div 5.29 \text{ m}^3 \text{ (Type A cask)} \approx \underline{419 \text{ Type A cask volumes/year}}$ .
- 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.,  $[319 \text{ m}^3/\text{year} + 34 \text{ m}^3/\text{year (Class B and C)}] \div 3.17 \text{ m}^3 \text{ (Type B cask)} \approx \underline{111 \text{ Type B cask volumes/year}}$ .

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<sup>8</sup> 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.

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<sup>3</sup>). Therefore, 485 Class A LLRW spent IER shipments (2568 m<sup>3</sup> ÷ 5.29 m<sup>3</sup> 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.
- Alternative 3—Long-term Onsite Storage of Class B and C Concentration Spent IERs, then Disposal: 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”.
  - Years 1-20--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.

- Year 21--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.

**(NOTE:** 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 in 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.)

- After Year 21--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.
- Alternative 4A—Volume Reduction of Class B and C Concentration Spent IERs at a Processing Facility, Long-term Storage, then Disposal: 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.,  $111 \div 5 \approx 23$ ). 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 <sup>a</sup>	2030
1B	1060	970	N/A	2030
2	N/A	N/A	1060	1060
3 (Years 1-20) <sup>b</sup>	N/A	N/A	838	838
3 (Year 21) <sup>b</sup>	N/A	N/A	5500	5500
3 (After Year 21) <sup>b,c</sup>	N/A	N/A	1060	1060
4A	222	46	838	1106
4B	222	46	838	1106

<sup>a</sup> N/A = not applicable.

<sup>b</sup> See text above for explanation of the three stages of Alternative 3.

<sup>c</sup> 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.,  $2030 \text{ trucks/year} \div 2000 \text{ hours/year} = 1.02 \text{ trucks/hour}$ ). 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.,  $970 \text{ trucks/year} \div 2000 \text{ hours/year} = 0.49 \text{ truck/hour}$ ). 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 ( $1060 \text{ trucks/year} \div 2000 \text{ hours/year} = 0.53 \text{ trucks/hour}$ ) 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 ( $838 \text{ trucks/year} \div 2000 \text{ hours/year} = 0.42 \text{ trucks/hour}$ ) 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 ( $5500 \text{ trucks/year} \div 2000 \text{ hours/year} = 2.75 \text{ trucks/hour}$ ) 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.,  $268 \text{ trucks/year} \div 2000 \text{ hours/year} = 0.14 \text{ trucks/hour}$ ). 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.,  $884 \text{ trucks/year} \div 2000 \text{ hours/year} = 0.44 \text{ trucks/hour}$ ). 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 <sup>a</sup>	ADDITIONAL TRUCKS NEAR WASTE DISPOSAL SITE <sup>a</sup>
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 <sup>b</sup>	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

<sup>a</sup> Based on an 8-hour operating day.

<sup>b</sup> 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.,  $1.13 \times 10^{10}$  metric tons per year ( $1.25 \times 10^{10}$  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.

**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 <sup>a</sup>		ANNUAL SPENT IER SHIPMENT WEIGHT (TONS) <sup>b</sup>	SPENT IER SHIPMENT WEIGHT AS % OF TOTAL TRACTOR-TRAILER FREIGHT WEIGHT <sup>c</sup>
	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%

<sup>a</sup> For shipments of both full and empty casks.

<sup>b</sup> 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).

<sup>c</sup> Calculated by dividing the annual spent IER shipment weights in tons by the total annual U.S. tractor-trailer shipment weight of  $1.25 \times 10^{10}$  tons (USDOT, 2010).

### 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 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<sup>9</sup>) 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 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 m (3.3 ft) from the lateral surface of the cask.<sup>10</sup> 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).

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<sup>9</sup> 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.

<sup>10</sup> 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.

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, from natural sources, of 3.11 mSv/year (311 mrem/year) (NCRP, 2009), as a percentage of this background dose. For populations, the annual collective dose is compared to 3.11 mSv (311 mrem) 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,  $6 \times 10^{-5}$  LCF per mSv (ISCORS, 2002). 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).<sup>11</sup>

### **A.3.2.1 Impacts on Individual Receptors**

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

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<sup>11</sup> 2010 total estimated cancer fatalities in the U.S. derived by the American Cancer Society from U.S. mortality data, 1969-2007.

- 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.<sup>12</sup> 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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<sup>12</sup> 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**

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

<sup>a</sup> 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.

<sup>b</sup> 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.

<sup>c</sup> 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.

<sup>d</sup> 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**

<b>INPUT PARAMETERS</b>	<b>Type A Cask (CNS 14-215)</b>	<b>Type B Cask (CNS 8-120B)</b>
<b>Average time at stop (hours)</b>	0.33	0.33
<b>Minimum distance of a nearby resident from the truck at the stop (m (ft))</b>	30 (98)	30 (98)
<b>Maximum distance of a nearby resident from the truck at the stop (m (mile))</b>	800 (0.50)	800 (0.50)
<b>Stop due to a truck accident (hours):</b> 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  $5.3 \times 10^{-5}$  (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<sup>13</sup>,

<sup>13</sup> 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.

and (2) the doses from exposures to multiple shipments are additive.<sup>14</sup> 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 <sup>a</sup>	LCF	LCF AS % 2010 ESTIMATED U.S. CANCER FATALITIES <sup>b</sup>
<b>Maximally exposed individual (MEI)</b>	A	2.4E-06	1E-05%	1.5E-10	3E-14%
	B	2.4E-06	1E-05%	1.5E-10	3E-14%
<b>Average person along the route: rural</b>	A	1.2E-09	4E-8%	7.3E-14	1E-17%
	B	1.2E-09	4E-8%	7.4E-14	1E-17%
<b>Average person along the route: suburban</b>	A	1.1E-09	4E-8%	6.7E-14	1E-17%
	B	1.1E-09	4E-8%	6.8E-14	1E-17%
<b>Average person along the route: urban</b>	A	2.3E-11	7E-10%	1.4E-15	3E-19%
	B	2.3E-11	7E-10%	1.4E-15	3E-19%
<b>Average resident near truck stop: rural</b>	A	4.3E-06	1E-04%	2.6E-10	5E-14%
	B	4.3E-06	1E-04%	2.6E-10	5E-14%
<b>Average resident near truck stop: suburban</b>	A	4.3E-06	1E-04%	2.6E-10	5E-14%
	B	4.3E-06	1E-04%	2.6E-10	5E-14%

<sup>a</sup> Average annual U.S. background dose = 3.11 mSv/year (NCRP, 2009).

<sup>b</sup> 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  $8 \times 10^{-7}$  to  $1.4 \times 10^{-1}$  percent of annual background, and would thus be representative of SMALL impacts to individual receptors. This conclusion is supported by the negligible LCFs associated with these doses, which range from about  $1 \times 10^{-16}$  to  $5 \times 10^{-11}$  percent of the total estimated fatal cancer fatalities in the United States in 2010.

<sup>14</sup> 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)
Maximally exposed individual (MEI)	A	2.2E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03	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	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	1.5E-07	7.7E-08	6.1E-08	4.6E-07	8.1E-08
	A+B % U.S. Annual Background	8E-02%	4E-02%	3E-02%	2E-01%	4E-02%	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	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	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	7.4E-11	3.9E-11	3.1E-11	2.3E-10	4.1E-11
	A+B % U.S. Annual Background	4E-05%	2E-05%	2E-05%	1E-04%	2E-05%	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	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	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	6.9E-11	3.6E-11	2.8E-11	2.2E-10	3.7E-11
	A+B % U.S. Annual Background	4E-05%	2E-05%	2E-05%	1E-04%	2E-05%	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	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	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-A-808	1.5E-12	7.4E-13	5.8E-13	4.5E-12	7.7E-13
	A+B % U.S. Annual Background	8E-07%	4E-07%	3E-07%	2E-06%	4E-07%	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	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	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	2.6E-07	1.4E-07	1.1E-07	8.3E-07	1.5E-07
	A+B % U.S. Annual Background	1.4E-01%	7.4E-02%	5.8E-02%	4.5E-01%	7.7E-02%	5E-11%	2E-11%	2E-11%	1E-10%	3E-11%

<sup>a</sup> Average annual U.S. background dose = 3.11 mSv/year (NCRP, 2009).

<sup>b</sup> Based on 2010 total estimated U.S. cancer fatalities of 569,495 (American Cancer Society, 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  $1.2 \times 10^{-9}$  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  $1.2 \times 10^{-5}$  person-mSv ( $1.2 \times 10^{-9}$  mSv x 10,000 persons =  $1.2 \times 10^{-5}$  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. 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 (TRANsgraphic 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, at the time the evaluation was originally conducted, TRAGIS was 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  $10^{-5}$  to  $10^{-4}$  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  $1 \times 10^{-8}$  percent), similarly representative of SMALL impacts.

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

DESTINATIONS <sup>a</sup>	STATES ON THE ROUTE	RURAL		SUBURBAN		URBAN	
		Route Length (km) <sup>b</sup>	Population Density (people/km <sup>2</sup> ) <sup>c</sup>	Route Length (km)	Population Density (people/km <sup>2</sup> )	Route Length (km)	Population Density (people/km <sup>2</sup> )
<b>Indian Point (NY) NPP to Waste Processing and Disposal Facilities</b>							
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
<b>Dresden (IL) NPP to Waste Processing and Disposal Facilities</b>							
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 <sup>a</sup>	STATES ON THE ROUTE	RURAL		SUBURBAN		URBAN	
		Route Length (km) <sup>b</sup>	Population Density (people/km <sup>2</sup> ) <sup>c</sup>	Route Length (km)	Population Density (people/km <sup>2</sup> )	Route Length (km)	Population Density (people/km <sup>2</sup> )
<b>Palo Verde (AZ) NPP to Waste Processing and Disposal Facilities</b>							
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
<b>Vogtle (GA) NPP to Waste Processing and Disposal Facilities</b>							
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
<b>Waste Processing Facility (TN) to Waste Disposal Facility (TX)</b>							
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

<sup>a</sup> 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).

<sup>b</sup> km = kilometers.

<sup>c</sup> km<sup>2</sup> = 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
<b>Type A Cask (CNS 14-215)</b>					
<b>Indian Point, NY</b>	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
<b>Dresden, IL</b>	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
<b>Palo Verde, AZ</b>	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
<b>Vogtle, GA</b>	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
<b>Processing (TN)</b>	Disposal (TX)	2.4E-05	2.0E-04	2.5E-06	2.2E-04
<b>Type B Cask (CNS 8-120B)</b>					
<b>Indian Point, NY</b>	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
<b>Dresden, IL</b>	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
<b>Palo Verde, AZ</b>	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
<b>Vogtle, GA</b>	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
<b>Processing (TN)</b>	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

**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 <sup>a</sup>				
		1A and 1B <sup>b</sup>	2 and 3 (after Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B <sup>b</sup>
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 <sup>c</sup>	2E-05%	1E-05%	1E-05%	5E-05%	1E-05%
	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 <sup>d</sup>	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	1E-05%	1E-05%	1E-05%	8E-05%	8E-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	5E-05%	1E-05%	1E-05%	6E-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%	1E-04%	8E-05%	5E-05%	8E-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%

<sup>a</sup> 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.

<sup>b</sup> 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.

<sup>c</sup> 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 3.11 mSv/year (NCRP, 2009), and then multiplying by 100 to obtain a percentage.

<sup>d</sup> 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.

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 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<sup>2</sup>) (0.77 square mile (mi<sup>2</sup>)).<sup>15</sup>

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  $4.3 \times 10^{-6}$  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 0.1 to 0.5 percent of background at rural and suburban truck 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  $4 \times 10^{-8}$  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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<sup>15</sup> 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<sup>2</sup>) in which these populations reside can be calculated as follows: Area =  $\pi \times [(0.8 \text{ km})^2 - (0.03 \text{ km})^2] = 2.0 \text{ km}^2$ .

**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 <sup>a</sup>	TRUCK REFUELING STOPS <sup>b</sup>
<b>Indian Point, NY</b>	Processing (TN)	779	1
	Processing (TN) + Disposal (TX)	2283	4
	Direct Disposal (TX)	1911	4
<b>Dresden, IL</b>	Processing(TN)	668	1
	Processing (TN) + Disposal (TX)	2171	2
	Direct Disposal (TX)	1244	5
<b>Palo Verde, AZ</b>	Processing (TN)	1534	3
	Processing (TN) + Disposal (TX)	3037	6
	Direct Disposal (TX)	533	1
<b>Vogtle, GA</b>	Processing (TN)	255	1 <sup>c</sup>
	Processing (TN) + Disposal (TX)	1758	4
	Direct Disposal (TX)	1622	3
<b>Processing (TN)</b>	Disposal (TX)	1503	3

<sup>a</sup> Summation of rural, suburban, and urban route distances from Table A-9.

<sup>b</sup> 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.

<sup>c</sup> 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 <sup>2</sup> ) <sup>a,b</sup>		POPULATION <sup>a,c</sup>	
		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

<sup>a</sup> All numbers in these columns are rounded numbers from calculations.

<sup>b</sup> 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.

<sup>c</sup> 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

**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 <sup>a,b</sup>					TOTAL ANNUAL LCF FROM SPENT IER SHIPMENTS TO RESIDENTS NEAR A TRUCK STOP, BY ALTERNATIVE <sup>a</sup>						
	1A and 1B <sup>c</sup>	2 and 3 (After Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B <sup>c</sup>		1A and 1B <sup>c</sup>	2 and 3 (After Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B <sup>c</sup>	
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 <sup>d</sup>	0.1%	0.1%	0.1%	0.4%	0.1%	% U.S. 2010 Estimated Cancer Fatalities <sup>e</sup>	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%	0.4%	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%	0.5%	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%	0.05%	0.03%	0.2%	0.05%	% 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%	0.4%	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%	0.4%	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%	0.5%	0.1%	% U.S. 2010 Estimated Cancer Fatalities	4E-08%	2E-08%	1E-08%	9E-09%	2E-08%

<sup>a</sup> 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.

<sup>b</sup> 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-4) multiplied by the population and half of the total annual shipments of Type A and Type B casks (from Table A-7) for each shipment route.

<sup>c</sup> 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 waste processing facility and from the waste processing facility to disposal.

<sup>d</sup> 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 3.11 mSv/year (NCRP, 2009), and multiplying by 100 to obtain a percentage.

<sup>e</sup> 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.

truck traffic accident and accident fatality rate information coupled with the total distances driven under each alternative with full and empty casks.

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**

<b>STATE</b>	<b>ACCIDENTS PER TRACTOR-TRAILER TRUCK-KM</b>	<b>STATE</b>	<b>ACCIDENTS PER TRACTOR-TRAILER TRUCK-KM</b>
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:

$$\text{State vehicle fatalities per vehicle-mile} = \frac{[(\text{vehicle fatalities}/100,000 \text{ people}) \times (\text{number of people driving})]}{(\text{vehicle-miles driven})}$$

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:

$$\text{State tractor-trailer truck fatalities per tractor-trailer-truck-mile} = (\text{vehicle fatalities per vehicle-mile}) \times (\text{fraction of fatalities for tractor-trailer trucks})$$

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:

$$\text{State tractor-trailer truck accidents per tractor-trailer truck-mile} = (\text{tractor-trailer truck fatalities}/\text{tractor-trailer-truck-mile}) \times (\text{tractor-trailer accidents} \div \text{tractor-trailer fatalities})$$

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 <sup>a</sup>	2 and 3 (After Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B <sup>a</sup>
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 <sup>b</sup>	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 <sup>c</sup>	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%

<sup>a</sup> 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.

<sup>b</sup> Based on 367,920 annual tractor-trailer truck accidents in 2009 (USDOT, 2011).

<sup>c</sup> 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:  $317.4 \text{ km} + 130 \text{ km} + 8.4 \text{ km} = 455.8 \text{ km}$   
In MD:  $5.7 \text{ km} + 12.3 \text{ km} + 1.4 \text{ km} = 19.4 \text{ km}$   
In NJ:  $40.2 \text{ km} + 67.6 \text{ km} + 14.2 \text{ km} = 122.0 \text{ km}$   
In NY:  $11.7 \text{ km} + 28.1 \text{ km} + 16.4 \text{ km} = 56.2 \text{ km}$   
In OK:  $428.2 \text{ km} + 98.2 \text{ km} + 8.4 \text{ km} = 535 \text{ km}$   
In PA:  $134.5 \text{ km} + 120.4 \text{ km} + 11 \text{ km} = 265.9 \text{ km}$   
In TN:  $496.4 \text{ km} + 241.4 \text{ km} + 31.3 \text{ km} = 769.1 \text{ km}$   
In TX:  $220 \text{ km} + 18.8 \text{ km} + 7.2 \text{ km} = 246 \text{ km}$   
In VA:  $282 \text{ km} + 230 \text{ km} + 9.7 \text{ km} = 521.7 \text{ km}$   
In WV:  $12.6 \text{ km} + 28.8 \text{ km} + 0.7 \text{ km} = 42.1 \text{ km}$

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

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

C. Annual State Tractor-Trailer Truck Accidents:  $A \times B \times 838 \text{ shipments/year}$

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:

$$0.315 + 0.00483 + 0.0293 + 0.0126 + 0.282 + 0.0941 + 0.277 + 0.0886 + 0.145 + 0.0197 \\ \approx \underline{1.3 \text{ accidents/year}}$$

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 =  $503 \div 367,920 = 0.00137$

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<sup>16</sup> 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<sup>17</sup>)] 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 purposes in the table, collective LCFs are calculated as percentages of 2010 total estimated U.S. cancer fatalities.

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<sup>16</sup> 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).

<sup>17</sup> 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 <sup>a</sup>	2 and 3 (After Year 21)	3 (Years 1-20)	3 (Year 21)	4A and 4B <sup>a</sup>
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 <sup>b</sup>	0.007%	0.006%	0.005%	0.032%	0.006%
	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 <sup>c</sup>	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 <sup>d</sup>	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	0.008%	0.003%	0.003%	0.020%	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%	0.007%	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%	0.016%	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%

<sup>a</sup> 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.

<sup>b</sup> 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 3.11 person-mSv/year (NCRP, 2009), and multiplying by 100 to obtain a percentage.

<sup>c</sup> From Table A-16.

<sup>d</sup> Based on 569,495 estimated cancer fatalities in the United States in 2010 (American Cancer Society, 2010).

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  $1.3 \times 10^{-4}$  mSv and  $7.8 \times 10^{-9}$ , respectively, and are the same regardless of transportation route, accident location, or alternative. This dose and LCF are 0.015 percent of background and  $2.3 \times 10^{-8}$  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<sup>18</sup> 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 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

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<sup>18</sup> 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.

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 ( $\mu\text{m}$ ) (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  $\mu\text{m}$ , 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.<sup>19</sup>

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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<sup>19</sup> 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<sub>2</sub> Values of the Mixtures**

1	2	3	4	5	6	7	8
RADIO-NUCLIDE	A <sub>2</sub> (i) VALUE	BWR <sup>a</sup> (Ci)	PWR <sup>b</sup> (Ci)	BWR Fraction	PWR Fraction	BWR f(i)/A <sub>2</sub> (i)	PWR f(i)/A <sub>2</sub> (i)
H-3 <sup>c</sup>	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	-- <sup>d</sup>	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
<b>Total Ci Content</b>		<b>417</b>	<b>135</b>		<b>Total f(i)/A<sub>2</sub>(i)</b>	<b>0.116/Ci</b>	<b>0.140/Ci</b>
					<b>A<sub>2</sub> for mixture 1</b> = $\frac{1}{\sum_I \frac{f(i)}{A_2(i)}}$	<b>8.61 Ci</b>	<b>7.15 Ci</b>

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

<sup>a</sup> BWR = boiling water reactor

<sup>b</sup> PWR = pressurized water reactor.

<sup>c</sup> A<sub>2</sub> value for this radionuclide is from 10 CFR 71, Appendix A, Table A-3.

<sup>d</sup> There is no useable A<sub>2</sub> 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:

$$A_2 \text{ for mixture} = \frac{1}{\sum_i \frac{f(i)}{A_2(i)}}$$

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:

$$D(r, t) = \frac{C K t}{A_2 r^2}$$

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:

$$K = \frac{50 \text{ mSv}(1\text{m})^2}{0.5 \text{ hr}} = 100 \frac{\text{mSv} \cdot \text{m}^2}{\text{hr}}$$

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 to 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:

$$D_{BWR} = \frac{8.61 \text{ Ci}}{8.61 \text{ Ci}} \times \frac{100 \frac{\text{mSv} \cdot \text{m}^2}{\text{hr}} \times 10 \text{ hr}}{(30 \text{ m})^2} = 1.11 \text{ mSv (111 mrem)}$$

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 36 percent and  $1 \times 10^{-8}$  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 <sup>a</sup>	36%	36%
MEI LCF	6.7E-05	6.7E-05
MEI LCF as % 2010 Estimated U.S. Cancer Fatalities <sup>b</sup>	1E-08%	1E-08%

<sup>a</sup> Based on average annual U.S. background dose of 3.11 mSv/year (NCRP, 2009).

<sup>b</sup> 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 in 10 CFR 71.73 and 71.51(a)(2) 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 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 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 <sup>a</sup>	FRACTION OF Ci INVENTORY RELEASED	
			Corrosion Product Particles	Spent Fuel Particles <sup>c</sup>
<b>No release<sup>b</sup></b>	1	0.9999	0.00	0.00
<b>Low-speed impact (less than 90 mph) into hard target</b>	2	6.1E-05	1.36E-03	1.02E-07
<b>High-speed impact (greater than 90 mph) into hard target</b>	3	5.9E-06	2.52E-03	6.71E-08
<b>Truck fire exposing the cask</b>	4	5E-07	1.83E-03	3.37E-07
<b>Truck fire exposing the cask with low-speed impact into hard target</b>	5	7.5E-08	3.16E-03	3.77E-06
<b>Truck fire exposing the cask with high-speed impact into hard target</b>	6	3E-10	3.17E-03	5.01E-06

Source: Sprung, 2007; Chapter 7.

<sup>a</sup> The conditional probability is the probability of the particular accident scenario in the event of an accident.

<sup>b</sup> 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.

<sup>c</sup> 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 ( $3.17 \times 10^{-3}$ ) 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<sup>2</sup>)<sup>20</sup>
- 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<sup>21</sup> of aerosolized particles: 0.05<sup>22</sup>
- Particle deposition velocity: 0.01 m/sec.<sup>23</sup>

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<sup>20</sup>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).

<sup>21</sup> Respirable fraction is the fraction of the aerosol that receptors would inhale all the way into their lungs, on average.

<sup>22</sup> Based on RADTRAN model constraint.

<sup>23</sup> Based on RADTRAN model constraint.

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 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:

$$\# \text{ of BWR Type B Shipments: } \frac{115 \text{ m}^3 \text{ Class B IERS} + 7 \text{ m}^3 \text{ Class C IERS}}{3.17 \text{ m}^3 \text{ per Type B Cask}} \approx 38 \text{ BWR Type B Shipments}$$

$$\# \text{ of PWR Type B Shipments: } \frac{204 \text{ m}^3 \text{ Class B IERS} + 27 \text{ m}^3 \text{ Class C IERS}}{3.17 \text{ m}^3 \text{ per Type B Cask}} \approx 73 \text{ PWR Type B Shipments}$$

*BWR Type B Curie Content per Shipment:*

$$\frac{17,600 \text{ Total curies per year for all BWR Reactors}}{38 \text{ BWR Type B Shipments}} = 467.4 \text{ Ci per BWR Type B Shipment}$$

*PWR Type B Curie Content per Shipment:*

$$\frac{9,256 \text{ Total curies per year for all PWR Reactors}}{73 \text{ PWR Type B Shipments}} = 127 \text{ Ci per PWR Type B Shipment}$$

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.<sup>24</sup> 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.

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<sup>24</sup> Tritium and C-14 would have been driven off as gases during thermal processing in Alternatives 4A and 4B.

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

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

<sup>a</sup> H-3 and C-14 would be present in the spent IER mixture as water and CO<sub>2</sub> and would therefore not be present in the processed material.

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 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-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	19%	6.4%
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	0.25%	0.079%
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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**APPENDIX B**  
**NRC RESPONSE TO PUBLIC COMMENTS ON THE**  
**DRAFT COMPARATIVE ENVIRONMENTAL EVALUATION OF ALTERNATIVES FOR**  
**HANDLING LOW-LEVEL RADIOACTIVE WASTE SPENT ION EXCHANGE RESINS**  
**FROM COMMERCIAL NUCLEAR POWER PLANTS**

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## B.1 Introduction

On September 20, 2012, the U.S. Nuclear Regulatory Commission (NRC) staff published a notice in the *Federal Register* (77 FR 58416) requesting public comments on the “Draft Comparative Environmental Evaluation of Alternatives for Handling Low-Level Radioactive Waste Spent Ion Exchange Resins from Commercial Nuclear Power Plants” (Draft Report) (NRC, 2012a). The public comment period was 120 days, ending on January 18, 2013. The NRC received comments from six commenters in response to the notice, including one governmental agency, four nongovernmental organizations, and one member of the general public, for a total of approximately 65 individual comments. This appendix presents all of the comments received and the staff’s response to each of those comments. The Final Report has been prepared in consideration of all the comments received, and includes revisions to the Draft Report based on some of these comments. Where applicable, report revisions are identified in the comment responses.

Table B-1 lists all of the commenters on the Draft Report in order of NRC-assigned Commenter Number, their name, their affiliation, and the Accession Number of the document in the NRC’s Agencywide Documents Access and Management System (ADAMS) in which their comments appear. The NRC staff also assigned a unique comment number to each individual comment. The comment numbers consist of two parts. The first part identifies the commenter (i.e., the Commenter Number in Table B-1). The second part identifies each individual comment to which the staff provides a response in Section B.2 below. For example, the first comment of Commenter Number 5 is Comment 5-01; the second comment is Comment 5-02; etc.

**Table B-1 Draft Report Commenter Identification**

<b>COMMENTER NUMBER</b>	<b>COMMENTER NAME</b>	<b>AFFILIATION</b>	<b>COMMENT DOCUMENT ADAMS ACCESSION NUMBER</b>
1	Kenneth Gunther	Member of the Public	ML12324A274
2	J. Scott Kirk	Waste Control Specialists LLC	ML13017A406
3	Rusty Lundberg	Utah Department of Environmental Quality, Division of Radiation Control	ML13025A354
4	Joseph DiCamillo	Studsvik, Inc.	ML13025A355
5	Thomas Magette	EnergySolutions	ML13025A356
6	Michael Dooley	Phoenix Energy of Nevada, LLC	ML13092A456

## B.2 Public Comments on the Draft Report and NRC Responses

The following are all of the comments received by the NRC on the Draft Report and the NRC staff’s responses to those comments. All of the comments are addressed in individual subsections below, in order of Commenter Number in Table B-1.

### **B.2.1 Commenter 1—Kenneth Gunter (Member of the Public)**

**Comment 1-01:** Nuclear waste disposal is no longer manageable. We must bring this expensive and disastrous industry to a rapid close.

**NRC Response:** *The NRC staff acknowledges this comment and appreciates the public participation. However, this comment is outside the scope of the Draft Report because it does not directly pertain to the comparative environmental evaluation of the six alternatives identified in the report for handling low-level radioactive waste (LLRW) spent ion exchange resins (IERS) from commercial nuclear power plants (NPPs). Because this comment is out of scope, no revisions are being incorporated into the report as a result of this comment.*

### **B.2.2 Commenter 2—J. Scott Kirk (Waste Control Specialists LLC (WCS))**

#### **Summary Comments**

**Comment 2-01:** There are significant differences in the environmental impacts presented by the various alternatives (for example, a doubling of risk associated with transportation). The distinction between impacts is too broad to support a useful comparison of alternatives if wide ranges of risk and impacts are all considered to be small, even if the entire range is considered to be acceptable.

**NRC Response:** *As discussed in Section 3.2 of the Draft Report, the environmental analysis is largely qualitative, which the staff believes is necessary and appropriate for the comparative environmental evaluation of the six generic, non-location-specific alternatives. This is because, for the most part, a reasonable set of quantitative evaluation factors could not feasibly be established for such broad, generalized alternatives. The staff considers this to be an acceptable limitation to the evaluation. Therefore, in Table 5 and Section 5.2 of the Draft Report, the staff endeavored to compare the alternatives to the extent possible within the constraints of this qualitative analysis. An exception is that the assessment of potential transportation impacts was initially conducted quantitatively, because quantifiable factors such as estimated numbers of shipments of full and empty shipping casks and representative transportation routes on which to base this analysis could be realistically projected. Thus, in the case of potential transportation impacts, a quantitative comparison of impacts of the alternatives was possible and therefore conducted.*

*Further, the staff assessed potential environmental impacts using its established standard of significance that is based on the standards of the Council on Environmental Quality's (CEQ's) regulations in Title 40 of the Code of Federal Regulations (40 CFR) 1508.27. Using this approach, each environmental impact was assigned a significance level of SMALL, MODERATE, or LARGE (NRC, 2003). These significance levels are defined in Section 3.2 of the report and repeated below:*

- *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.*

*As the commenter correctly notes, there are differences in the environmental impacts presented by the various alternatives. For example, the total miles spent IERs are transported under one alternative might be double the total miles spent IERs are transported under another alternative, thus resulting in a doubling of the magnitude of certain potential environmental impacts. However, if the environmental effects of such differences were determined by the staff to not be detectable or so minor that they would neither destabilize nor noticeably alter any important attribute of the resource, as was the case for nearly all the qualitative and quantitative impacts assessed in the evaluation, then the impacts were appropriately assigned a significance level of SMALL. Under these circumstances, the differences between the impacts of the various alternatives were considered small. Accordingly, no revisions were made to the report as a result of this comment.*

**Comment 2-02:** The evaluation assumes that the current volume of resin shipments from nuclear power plants comprise the entire universe of shipments in downblending/processing alternatives. In fact, significantly larger numbers of shipments of Class A material are likely to be required from non-power plant facilities to provide sufficient low-activity feedstock to accomplish the downblending. The impacts of the additional shipments of these materials to a central processing facility are not addressed in the evaluation.

**NRC Response:** *The scope of the evaluation was established in Option 2 in the NRC staff's paper for the Commission, SECY-10-0043, "Blending of Low-Level Radioactive Waste," April 7, 2010 (NRC, 2010a). Option 2 stated, "As part of the NEPA analysis for this rulemaking,<sup>1</sup> 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** (emphasis added)." 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). As such, the Commission directed the staff to conduct a comparative environmental evaluation of a specified set of alternatives for managing spent IERs. Furthermore, the staff's intent in SECY-10-0043, Option 2, was that the comparative environmental evaluation would be conducted for alternatives for managing spent IERs from NPPs, including blending. As discussed in the Background section of SECY-10-0043 and the Enclosure to SECY-10-0043 (NRC, 2010c), this type of waste was being considered for blending because it can be blended into a relatively uniform mixture; these resins account for*

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<sup>1</sup> NRC Staff Note: *The rulemaking referenced here is the 10 CFR Part 61 rulemaking that the Commission directed the staff to conduct in its March 18, 2009, Staff Requirements Memorandum SRM-SECY-08-0147, "Staff Requirements – SECY-08-0147 – Response to Commission Order CLI-05-20 Regarding Depleted Uranium" (NRC, 2009).*

*about half of the volume of Class B and C waste generated each year; and these resins were the focus of a waste processor's expanded LLRW blending at its facility in the State of Tennessee. Additionally, the Commission did not direct the staff to study the technical or economic feasibility of implementing any of the alternatives. Thus, specific to the comment, the evaluation did not include a determination of whether significantly larger numbers of shipments of Class A material from non-power plant facilities would be required to accomplish the blending of spent IERs from NPPs. For the above reasons, the impacts of additional shipments of materials other than spent IERs from commercial NPPs are not addressed in the evaluation and no revision to the report was made as a result of this comment.*

**Comment 2-03:** The evaluation equates alternatives with inherently low risk with more complex alternatives with significantly greater risk of environmental impact, presuming that the impacts are mitigated by administrative and engineering controls. There is no apparent consideration for the impact of a failure in the administrative or engineering controls in complex radioactive waste treatment systems. This seems both inadequate and incongruous with the treatment of failures of administrative and engineering controls during transportation, which the evaluation does attempt to address.

**NRC Response:** *Taking credit for the mitigation of potential environmental impacts, by such factors as administrative and engineering controls, is a standard and accepted practice in environmental evaluations performed by the NRC and other Federal agencies. These evaluations reasonably assume that if any mitigation measures were to fail, appropriate corrective measures would be taken to avoid or minimize adverse environmental impacts.*

*Further, as discussed in Section 3.3 of the report, the evaluation did not consider accidents and other off-normal conditions, which could include the potential failure of administrative and engineering controls, because it is not feasible to develop accident and off-normal event scenarios for generic, non-location-specific alternatives. Instead, the evaluation 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 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. On the other hand, the evaluation did address the potential impacts of transportation accidents because they are not unique to any location or alternative, and could be addressed generically using factors such as estimated numbers of shipments and hypothetical transportation routes. Accordingly, no revisions were made as a result of this comment.*

**Comment 2-04:** Similarly, the report does not consider the additional significant worker doses that would occur due to the double handling and treatment of the waste in the processing alternatives when compared to direct disposal. Additional occupational dose, controlled by the processing licensee to acceptable limits, is additional dose nonetheless. This additional worker dose does not comply with ALARA<sup>2</sup> principles and should be considered in the impact

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<sup>2</sup> NRC Staff Note: ALARA = as low as reasonably achievable.

assessment, even if the expectation is that the dose to any given individual will be within regulatory limits.

**NRC Response:** *In Section 5.1.2.5, Table 5, and Section 5.2.5, the report considered that worker activities for handling, processing, storage, and disposal of spent IERs in all six alternatives must comply with NRC, Agreement State, Occupational Safety and Health Administration, ALARA, and other worker protection requirements and standard operating procedures, as applicable, thus limiting any radiological occupational exposures to acceptable levels for all the alternatives evaluated. The NRC staff recognizes that there would be differences in occupational doses between the various alternatives; however, the fact that the doses would be within acceptable levels resulted in the staff's finding that the potential occupational health impacts would be SMALL in all cases.*

*Furthermore, the staff does not agree with the commenter's assertion that ALARA principles are violated because some alternatives have higher worker doses than other alternatives. According to the NRC's definition in 10 CFR 20.1003, "ALARA...means making every reasonable effort to maintain exposures to radiation as far below the dose limits...as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest (emphasis added)." Accordingly, the staff believes that ALARA principles apply individually to licensed activities and would not appropriately be used to compare the worker doses among different licensed activities. No revisions were made to the report as a result of this comment.*

**Comment 2-05:** The evaluation understates transportation impacts with an assertion that Class A resin shipments will occur in Type A casks. In fact, significant amounts of Class A resin (particularly the low activity feedstock from non-power facilities) are unlikely to require the use of an NRC approved package.

**NRC Response:** *The commenter provided a more detailed comment about the shipping of Class A resins in non-NRC approved packages in Comment 2-19A below; and the NRC response to that aspect of Comment 2-05 is provided there. Low activity feedstock from non-power facilities is not addressed in the NRC's comparative environmental evaluation for reasons discussed in the response to Comment 2-02 above.*

**Comment 2-06:** Downblending and thermal processing represent a strategy in which the requirements for packaging and disposal applicable to a given curie of waste are dramatically reduced. This reduction of standards seems certain to reduce the level of public and environmental protection against exposure to the radioactivity in these materials. The current evaluation does not address the impact of the reduced environmental protection measures. In order to meet its stated objectives, the evaluation must address the environmental impacts of diversion of thousands of curies of radioactivity from engineered disposal in robust facilities to alternatives featuring conventional disposal in standard Class A landfills with their correspondingly lower level of environmental protection.

**NRC Response:** *The staff disagrees that the level of environmental protection at Class A landfills would be less than at Class B and C landfills. In the licensing requirements for disposal of radioactive waste, found in 10 CFR Part 61, the level of protection is defined by the dose limits, which are 25 millirem (mrem)/year for an offsite member of the public and 500 mrem/year for an inadvertent intruder into the disposal facility.<sup>3</sup> Even though some waste could be reduced from Class B and C concentrations to Class A concentrations as a result of blending, the level of protection that must be met in 10 CFR Part 61 remains the same, because the dose limits are the same for Class A, B and C disposal facilities. In all three cases, the environmental and public health impacts are SMALL (i.e., they are not more than the dose limits cited above). The commenter has defined “level of protection” by the controls that are used to manage the hazard of the waste, and the controls are commensurate with the hazard, so that the same required level of protection is achieved. Thus, because the Class B and C wastes have higher concentrations than the Class A wastes, the Class B and C wastes have more controls for managing risk than Class A wastes. The NRC has developed standards and guidance for managing Class A waste, including blended waste, to achieve the required level of protection. No change to the report was made as a result of this comment.*

### **Detailed Comments**

**Comment 2-07:** Executive Summary, Introduction and Purpose

Evaluation Content: The Staff Requirements, SECY-10-0043 accepted the Option 2 recommendation that disposal of blended ion exchange resins from a central processing facility would be compared to direct disposal of the resins as part of the NEPA analysis for this rulemaking.

Comment: The draft Branch Technical Position (BTP) on Blending of Low Level Radioactive Waste provides for the blending of many waste streams in addition to ion exchange resins. The environmental impacts of blending a variety of waste streams may not be adequately addressed by consideration of ion exchange resins alone. The environmental evaluation of alternatives should include other waste streams, or, include a determination that the evaluation of resin processing and disposal effectively addresses the environmental impacts of processing other waste streams considered by the BTP. As an alternative, the BTP should state that blending only applies to resins.

**NRC Response:** *As discussed in the response to Comment 2-02 above, the scope of the evaluation was defined in Option 2 of the NRC staff’s paper for the Commission, SECY-10-0043 (NRC, 2010a), and approved by the Commission in SRM-SECY-10-0043 (NRC, 2010b); and that scope is specific to blending “ion exchange resins.” Although the NRC is not legally obligated to prepare an environmental impact evaluation, the Commission directed the NRC staff to prepare an analysis of the environmental impacts of resin blending. The Commission, however, did not direct the staff to evaluate the possible environmental impacts of blending other materials.*

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<sup>3</sup> NRC Staff Note: 500 millirem/year is not contained in the regulation, but is the basis for the waste classification tables in 10 CFR 61.55.

*The commenter is correct in stating that the 1995 BTP is being revised, and that this BTP, as well as earlier versions, allow blending of other physically similar wastes that are amenable to mixing to achieve relatively uniform radionuclide concentrations. However, as measured in terms of volume, and as measured in terms of activity, the staff believes that the blending of spent IERs from commercial NPPs is the most significant blending operation that could occur in the U.S. No change was made as a result of this comment.*

**Comment 2-08:** Page viii, 3<sup>rd</sup> full paragraph (and page 103, 1<sup>st</sup> full paragraph, page 2-4 last paragraph)

Evaluation Content: *[WCS] 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.*

Comment: The evaluation presents the straightforward compact import petition process as unduly restrictive. In particular, it is not correct to state that any of the US NPPs have "no access" to Class B and C disposal. No petition to import Class B and C resin to WCS has ever been denied, so the term "limited access" also seems a misnomer. Finally, the curie and volume limits on waste imports stated in the report were initially established by the Texas legislation before the WCS facility opened and began accepting waste. Based on the results of the ongoing TCEQ<sup>4</sup> updated capacity report, these limits may be increased. We do not agree with the characterization of our license limits as restricting the availability of direct Class B and C resin disposal at the pace at which it is likely to occur.

**NRC Response:** *The NRC acknowledges that the WCS LLRW disposal facility can accept out-of-compact Class A, B, and C LLRW (Herness, 2013). Accordingly, the text in the Executive Summary and Sections 1 and 2.2 has been revised to recognize that WCS can accept out-of-compact Class A, B, and C LLRW for disposal (subject to annual limits and case-by-case import petition approval by the Texas Compact), and that all NPPs potentially have access to a disposal facility for their Class B and C spent IERs at this time. However, as also discussed in the revised text of the report, the scope of the evaluation was defined at a time when, in fact, the majority of NPPs had no access, or limited access, to Class B and C disposal. Therefore, the Final Report will continue to address all six alternatives in the same manner as in the Draft Report.*

**Comment 2-09:** Page ix, footnote 1 (and page 1-3, 1<sup>st</sup> partial paragraph)

Evaluation Content: *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*

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<sup>4</sup> NRC Staff Note: TCEQ = Texas Commission on Environmental Quality.

*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.*

Comment: The distinction between waste concentration and waste class seems unnecessary. It is clear, even in the Draft Evaluation's descriptions of the Alternatives 1A and 1B, that "Class A, B, and C spent IER LLRW" will be blended intentionally "to produce Class A waste." Admittedly, 10 CFR Appendix G, Section III A, does not require that waste classification be performed prior to shipment to a centralized waste blending or thermal treatment facility. Nonetheless, it is transparent to the most casual observer that spent materials with no further use are waste. Further, the classification of the waste could readily be determined based on the characterization performed to support shipment, and it is obvious that the intent of the blending is to reduce the waste classification of Class B and C wastes by combination with large volumes of waste materials of a lesser classification.

***NRC Response:*** *The comment is noted. However, as stated in the report, the regulations do not require waste to be characterized until shipped for disposal, so the characterization of spent IERs that are not yet being shipped for disposal as Class A, B or C concentration spent IERs is correct. Based on current information, the report will remain unchanged in this regard.*

#### **Comments 2-10A, B, and C: General Content**

Evaluation Content: Radiological impacts associated with direct disposal are generally described as "somewhat less" than Alternatives involving long term storage or thermal treatment.

Comment 2-10A: The safety and radiological impacts of direct disposal are considerably less than for alternatives involving blending and thermal treatment. For example, the number of shipments required for processing necessarily doubles (since an extra shipment to a central processing facility is required). Indeed, trucks on the road vary two and a half times (0.0002-0.0005% of freight traffic, pg xiv), and public dose from truck varies by two and one third times (0.03 to 0.07% of US average background). The dose to workers in the alternatives involving thermal treatment and/or storage can be expected to be significantly higher than that for workers at a disposal facility where waste packages are not opened and exposure is minimal. The distinction between small, moderate, and large impacts is perhaps too broad to support a comparison of Alternatives if a demonstrated doubling of transportation risk and obvious occupations exposure risk remains "small".

***NRC Response:*** *The response to Comment 2-01 above provides the basis and justification for the NRC's comparative environmental impact evaluation approach, and for the determinations of potential impacts to be SMALL. That response also discusses why the differences between the impacts of the various alternatives were considered small. However, the staff has considered that the characterization of certain potential environmental impacts in the evaluation as being "somewhat less" or "somewhat greater" than others may not be meaningful, given the qualitative nature of the evaluation. Therefore, the word "somewhat" has been removed wherever it appears in the report as a part of a descriptor of the magnitude of potential environmental impacts.*

Comment 2-10B: Similarly, while a licensee would be expected to assure the safety of workers during the extra offloading, thermal treatment, and plant maintenance procedures that are required for thermal processing, the exposure to workers in a direct disposal scenario is significantly less. The additional occupational dose to workers in the processing alternatives is not considered as an additional impact, because the occupational dose is assumed to be controlled by the licensee. This assumption may be correct, but failure to consider the additional dose associated with processing does not meet ALARA principals and may not support an accurate comparison of the alternatives under evaluation.

***NRC Response:*** See response to Comment 2-04 above concerning the evaluation of worker doses and ALARA principles.

Comment 2-10C: In addition, the report appears to equate alternatives with inherently low risk with more complex alternatives with significantly greater risks because they can be mitigated by administrative and engineering controls. However, the risks (particularly air quality and public and occupational health) associated with the bulk blending and thermal treatment of high activity resins present an apparent "unique risk" that should be considered as described in 40 CFR 1508.27(b)(5). There are numerous risks inherent in the bulk processing of resins that are unique to that process and do not present themselves at all in a direct disposal option where resins are never removed from their packaging/liner. Indeed, it appears the draft report only addresses "significance" as defined in 40 CFR 1508.27, and does not attempt to address risk as it is included in the definition of "intensity" (except for transportation risk). There is no apparent consideration for the impact of a failure in the administrative or engineering controls in complex radioactive waste treatment systems. Also, the cumulative risk (40 CFR 1508.7) of repeated transportation events and complex and technology-intensive waste treatment do not appear to have been considered in the evaluation. Again, the distinction between impacts is too broad to support a useful comparison of alternatives if wide ranges of risk and impacts are all considered to be small; even if the entire range is ultimately considered to be acceptable.

The risks of long term storage are perhaps less severe, but there are risks unique to alternatives featuring storage, i.e. container/liner failure in storage, exposure to workers during extended storage, and accidental or malevolent intrusion. These risks, however well-controlled, are still additional risks that are not present in less complex alternatives (e.g. direct disposal).

***NRC Response:*** The NRC staff's consideration of mitigation of potential impacts using administrative or engineering controls and the impacts of failure of such controls is discussed in the response to Comment 2-03 above. The staff acknowledges that all aspects of all of the alternatives, including transportation, blending, thermal treatment, long-term storage, and disposal, have several associated inherent "unique risks." In the report, the staff assessed these potential risks, or impacts, within the limitations of a qualitative evaluation of generic, non-location-specific alternatives, and using the NRC's established standard of significance that is based on the standards of the CEQ's regulations in 40 CFR 1508.27, as discussed in the response to Comment 2-01 above. As discussed in Section 3.2 of the report, this evaluation was conducted under the reasonable assumption that all blending, thermal treatment, long-term storage, and disposal activities would be conducted at licensed facilities and in compliance with

*all applicable Federal, State, and local legal and regulatory requirements. Finally, the staff also acknowledges that the environmental impacts of all the alternatives could include potential cumulative effects. However, as also discussed in Section 3.2, cumulative impacts (as defined in the CEQ's regulations in 40 CFR 1508.7) were not assessed in the evaluation because there is no basis here for determining the past, present, and reasonably foreseeable future actions on which such an analysis could be based for generic, non-location specific alternatives.*

**Comment 2-11:** Page 3-3, Description of Alternative 3

Comment: Alternative 3 includes the long term, 20-year storage of IERs as being necessary until a Class B and C disposal facility becomes available, and states that *"commercial NPPs could eventually have a disposal pathway for their Class B and C resins."* The draft language should be adjusted since WCS provides this alternative today. Similarly, the description of Alternative 4A, and footnote #9 do not properly recognize the current availability of WCS as a Class B and C disposal option for commercial NPPs.

**NRC Response:** *As discussed in the response to Comment 2-08 above, the text in the Executive Summary and Sections 1 and 2.2 has been revised to recognize that WCS can accept out-of compact Class A, B, and C LLRW for disposal (subject to annual limits and case-by-case import petition approval by the Texas Compact), and that all NPPs potentially have access to a disposal facility for their Class B and C spent IERs at this time. However, as indicated in the response to Comment 2-02 above, "onsite storage of certain wastes when disposal is not possible," as described in Alternative 3, is one of the alternatives specified for evaluation in Option 2 of SECY-10-0043 (NRC, 2010a). Therefore, the description of Alternative 3 in the report will remain unchanged. As for Alternative 4A, this report is an environmental evaluation of generic, non-location-specific alternatives for handling low-level radioactive waste spent ion exchange resins and staff believes that Alternative 4A is a valid generic scenario for evaluation. Accordingly, Alternative 4A has been retained for consideration in the evaluation, and the description of Alternative 4A and the text of footnote #9 referenced in the comment (footnote 13 in the Final Report) have not been changed as a result of this comment.*

**Comment 2-12:** Page 4-4, Section 4.2.1, Description of alternative 1A, Mechanical Mixing

Comment: The NRC presumption is that compacted IERs require either hydraulic or mechanical agitation before they can be removed from the HICs<sup>5</sup> or liners. Hydraulic agitation is the technique generally used to loosen and sluice resin materials. However, the NRC goes on to say that the mechanical blending of differing Class concentrations of resins would produce little ancillary waste because it would use small quantities of water. However, the assumption that mechanical blending does not use significant quantities of water does not accurately reflect the process. Indeed, mechanical mixing alone may not add much water, but the hydraulic agitation and sluicing required to remove compacted resins from their HICs/liners does generate large amounts of water that should not be overlooked in the environmental evaluation of

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<sup>5</sup> NRC Staff Note: HIC = High Integrity Container.

alternative. The fact that mechanical blending has never been used on a commercial scale is acknowledged, making the extent of environmental impact difficult to assess. But other proven options, like direct disposal, introduce no water at all, and this fact should be considered favorably in the evaluation of alternatives.

***NRC Response:*** *The NRC staff agrees that mechanical blending has never been used on a commercial scale. If mechanical blending is used on a commercial scale, the staff believes that facility operators would optimize their processes to minimize the generation of ancillary liquid wastes, and would handle any waste liquids generated in accordance with applicable regulatory requirements. The commenter does not provide sufficient justification to alter the description of Alternative 1A or the assessment of the potential impacts of this alternative in the report.*

*The staff further notes that in a proven option like direct disposal, water enters or infiltrates into disposal cells during precipitation events, and water may also be introduced as a result of other natural processes or intentional dust control. However, as with all the other alternatives, the staff has reasonably assumed that any impacts would be minimized through appropriate mitigation measures. No changes were made to the report as a result of this comment.*

**Comment 2-13:** Page 4-6, Section 4.2.2, Description of alternative 1B, Blending with Thermal Processing

Comment: The description of the ion exchange resin 'destructive distillation' process notes that 1 million gallons of water will be needed each year to support the thermal destruction of blended resins. This is described as not being unusual for a small industrial facility. However, the use of 1 million gallons of water per year to decompose highly radioactive resins seems to be summarily dismissed in the environmental evaluation, and seems to have no weight at all in comparing this complex and resource-intensive thermal destruction process to simpler processes which introduce no water and produce no additional wastes whatsoever (e.g. direct disposal).

***NRC Response:*** *The comment highlights an important point; an individual reading the report may not understand the relative significance of the 1 million gallon figure. Without context, the use of 1 million gallons of water per year may seem to the reader like a significant impact. To place this in perspective, the U.S. Environmental Protection Agency (EPA) reports that, on average, a family of four in the U.S. can use 400 gallons of water every day (EPA, 2008). This means that a mere seven households of four persons each would use about 1 million gallons of water per year (7 four-person households x 400 gallons per day per household x 365 days per year ≈ 1 million gallons per year). Thus, the use of this quantity of water would, indeed, represent a SMALL impact.*

*Regarding the commenter's statement that direct disposal introduces no water, the introduction of water in the direct disposal alternative is discussed in the response to Comment 2-12 above.*

## **Comments 2-14A and B: General Comment on Blending/Processing**

Comment 2-14A: The discussion of resin blending and processing presumes that HICs/liners containing resins do not contain other waste materials (e.g. filters and other contaminated objects). While some plants control and limit HIC/liner contents to resins alone, many view the HIC/liner as a waste container and seek to fill the volume to the extent practical with wastes that can be similarly characterized or profiled. The environmental evaluation fails to address two consequences of this likely inclusion: (1) Since these included materials cannot reasonably be considered feedstock for resin blending, it may not be compliant practice to ship these materials to a processor without designating the shipment as "waste", and, (2) The discussion of resin processing as a smooth running process operating on like materials of similar physical process seems to fail to evaluate the complications and possible environmental and dose impacts of encountering these materials. These complications include process interventions required to address the likely presence of non-resin waste items, and variation in the properties of the resins themselves.

***NRC Response:*** *The comment would be accurate for wastes shipped for direct disposal. However, the NRC staff believes it is reasonable to assume that blending and thermal processing facilities would take steps to ensure that only acceptable materials are included in material shipments. For example, ensuring that only acceptable materials are included in shipments would serve to promote smooth operation of the processing facilities and prevent returns of unacceptable shipments. Such steps could include waste acceptance criteria (WAC) prohibiting non-spent IER materials and penalties for violations of the waste processor's WAC. No changes were made to the report as a result of this comment.*

Comment 2-14B: Dilution with clean materials is clearly prohibited in waste management practice. However, blending and thermal processing generally include the addition of clean materials for use as stabilizing media. The environmental evaluation and other requirements or guidance should be clear on the limits to which stabilization with arguably diluting media is an acceptable practice.

***NRC Response:*** *The NRC's revised BTP will address the blending process, and will recommend against the introduction of clean materials for the sole purpose of dilution. NRC regulations do not prohibit dilution, but NRC proposed guidance recommends constraints on it. For example, in Table C of the May 2012 draft revised BTP (NRC, 2012b), the NRC states that clean (i.e., non-radioactive) materials added to a mixture "should have a purpose other than reducing the waste class, such as waste stabilization or process control. Consistent with other provisions in this BTP, extreme measures to lower the waste classification should be avoided." No changes were made to the report as a result of this comment.*

## **Comment 2-15: General Comment on Tariffs**

Comment: In recent years, some states (notably Iowa and Indiana) have established tariffs to shipments of radioactive wastes being transported through their states. These tariffs are generally established to fund emergency and environmental response to accidents involving radioactive waste, and are levied in part, based on the identification of the shipment as a waste

shipment (e.g. the presence of an NRC 541/542 form). The establishment of a centralized resin processing facility in one state may burden neighboring states with the responsibility for responding to the accidents involving the shipments of non-waste resin feedstock. However, without the revenues associated with the shipment of waste, states may not be able to mount the appropriate response to an environmental release. The existence of a centralized processing facility essentially doubles the number of radioactive materials shipments, even as the artificial non-waste designation thwarts states' efforts to collect revenues for transportation accident emergency response.

**NRC Response:** *The comment is noted. However, Option 2 of SECY-10-0043 (NRC, 2010a) included “disposal of blended ion exchange resins from a central processing facility (emphasis added)” as an alternative to be included in the scope of the comparative environmental evaluation (see response to Comment 2-02 above). It is too fine of a detail for a generic, non-location-specific evaluation to consider a small number of isolated, State-imposed tariffs and their impact on emergency responses to accidents involving environmental releases. It is assumed that the commenter’s reference to the “artificial non-waste designation” relates to the issue the commenter raised in Comment 2-09 above, in which the commenter questioned the need for the distinction between waste concentration and waste class. Setting aside the tariff issue, the NRC staff believes it is reasonable to assume for this evaluation that releases of radioactive materials during transportation would be appropriately handled regardless of whether or not the materials have been classified as waste. No changes were made to the report as a result of this comment.*

**Comment 2-16:** Section 5.1.2. Resource and Impact Area-Specific Methodologies and Assumptions

Comment: The environmental evaluation is devoid of any discussion of the differing levels of environmental protection provided the end-state disposal options. There is no distinction made between the level of environmental protection provided for safe disposal of smaller quantities of Class B and C wastes in a robust facility specifically designed to accept those materials, and the relative risk of disposal in standard landfills accepting much larger quantities of Class A wastes. Downblending and thermal processing dramatically increases the curie content that may be disposed in Class A facilities with minimal protection for the environment. In contrast, Class B and C facilities are specifically designed with robust protections that directly address the disposal risks presented by the huge number of curies in these waste materials.

Downblending and thermal processing represent a strategy in which the requirements for packaging and disposal applicable to a given curie of waste are effectively reduced. This reduction of standards seems certain to reduce the level of public and environmental protection against exposure. In order to meet its stated objectives, the evaluation must address the environmental impacts of diversion of thousands of curies of radioactivity from engineered disposal in robust facilities to conventional disposal in standard Class A landfills.

**NRC Response:** *Regarding the differing levels of protection afforded by the disposal of Class B and C LLRW as compared to disposal of Class A LLRW, see response to Comment 2-06 above. In response to the general comment that “downblending” represents a strategy in which*

*the requirements for packaging applicable to a given curie of waste are effectively reduced, the classification of the final waste product dictates the packaging requirements that must be met and the NRC staff believes that compliance with the NRC radioactive materials packaging and transportation regulations in 10 CFR Part 71 ensures the safe transport of spent IERs of all classes, pre- or post-blending.*

**Comment 2-17:** Section 5.1.2.7 Transportation Impacts

Comment: The section states that the exposures of radiation workers (e.g. truck crews, package handlers, and inspectors) are not considered in the analysis because these are trained radiation workers. Failure to consider the additional person-rem exposure of additional personnel resulting from the increased number of transportation events necessary to ship to an intermediate processing facility seems inappropriate. Controlled or not, the involvement and exposure of additional personnel in roughly double the number of transportation events should be considered in the evaluation of alternatives as an additional impact.

**NRC Response:** *The complete discussion in Section 5.1.2.7 of the report states, “Note that exposures of ‘radiation workers’ (e.g., truck crews, package handlers, and inspectors) are not considered in the 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.” Had potential radiation doses to these workers been considered, the staff would have concluded that the doses would be within regulatory limits, an impact that would have been assigned a significance level of SMALL. See also the response to Comment 2-04 above regarding occupational health impacts. Accordingly, no change to the report was made in response to this comment.*

**Comments 2-18A and B:** General Treatment of Risk:

Comment 2-18A: The transportation analysis appropriately considers the risk of accidents. Yet this is the only aspect of the environmental evaluation that appears to consider risk. The evaluation recognizes that transportation risks exist even though transportation is regulated, controlled, and executed by trained personnel. However, the evaluation presumes that risk is eliminated (or already satisfactorily addressed) for many other activities because these other activities are subject to similar controls. For example, there is no discussion of the environmental risk associated with the potential failure of environmental controls at a processing facility. This dismissive treatment of other environmental risks in the evaluation seems inappropriate, and fails to address the increased risk of public and environmental exposure associated with blending and processing tasks of increasing complexity. This is particularly obvious in omission of any assessment of disposal risk.

**NRC Response:** *See response to Comment 2-03 above.*

Comment 2-18B: In the evaluation, disposal of downblended material at Class A facilities is presumed to be in accordance with the Class A disposal license, and therefore, environmentally acceptable. But the diversion of thousands of curies of waste from robust disposal facilities specifically designed to protect the environment, to disposal in facilities that do not provide

equivalent environmental protection from these curies, is not discussed. This focus of the evaluation is too narrow, and it fails to consider the broad systematic effects of downblending on the environment. In this way, the evaluation fails to meet its stated objective to compare the environmental impacts of disposal of downblended materials in a conventional Class A landfill with the engineered disposal of Class B and C resins in a facility specifically designed for that purpose.

**NRC Response:** See response to Comment 2-06 above.

### **Comments 2-19A and B:** 5.1.2.7.3 Radiological Impacts (of Transportation Accidents)

Comment 2-19A: The evaluation considers transportation events involving only Type A and Type B casks, with the underlying assumption that shipments of Class A resins will benefit from the protections afforded by an approved cask design. This overstates the level of protection provided for most Class A shipments, and may result in an unduly low misrepresentation of the calculated risk of public exposure from an accident involving Class A material.

First, the evaluation's assertion that Type A casks can carry no more than an  $A_2$  value is incorrect. It quite common for Type A casks to be used for their shielding properties for materials meeting LSA-II<sup>6</sup> shipping criteria. The Department of Transportation (DOT) does not limit to the activity that may be transported on a conveyance loaded with LSA-II non-combustible solids. An 8-120A cask, loaded to its 20,000 lb.<sup>7</sup> capacity with LSA-II material, could contain up to 900  $A_2$  values; and a 21-300 cask could contain over 1,200  $A_2$  values (based on the cask capacity and the  $10^{-4}$   $A_2/g$ <sup>8</sup> LSA-II concentration limit).

Second, very large quantities of low-level Class A resin will likely be needed to effectively downblend the more highly contaminated Class B and C resins. The vast majority of Class A waste (which includes this resin population when it is not being used for downblending) is currently shipped in IP-1 or IP-II packages<sup>9</sup> that are deemed compliant by the shipper; and do not benefit from the design requirements or NRC approval requirements of Type A or B casks. The presumed use of Type A casks for large quantities of low-activity feedstock is an overstatement of the protection afforded by the packaging of these materials, and may under-represent the transportation risks associated with downblending and processing alternatives.

**NRC Response:** *Although the commenter is correct that the evaluation considers transportation events involving only Type A and Type B shipping casks, the commenter is not correct that there is an underlying assumption that shipments of Class A resins will benefit from the protections afforded by an approved cask design. No such assumption has been made in conducting the evaluation. The commenter is also correct that some Class A spent IERs are shipped in industrial packages as LSA material, and that the total curies in a single industrial package of LSA could exceed the  $A_2$  value. The report text has been modified as indicated*

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<sup>6</sup> NRC Staff Note: LSA = low specific activity.

<sup>7</sup> NRC Staff Note: lb. = pound.

<sup>8</sup> NRC Staff Note: g = gram.

<sup>9</sup> NRC Staff Note: IP = Industrial Package.

below to account for these factors. However, for reasons discussed below, the NRC staff disagrees with the commenter's assertions that the assumed use of Type A casks overstates the protection afforded these materials during transport and misrepresents the calculated risk of public exposure from an accident involving Class A material as unduly low. On the contrary, the assumption that all Class A spent IER shipments would be in Type A shipping casks results in a more conservative estimation of potential environmental impacts than if industrial packages would be used for some shipments. Justification for basing the analysis on shipment of spent IERs solely in Type A and Type B shipping casks is provided, and the analysis in the report remains unchanged. Finally, the commenter's contention that very large quantities of low-level Class A resin will likely be needed to effectively "downblend" the more highly contaminated Class B and C resins is addressed in the response to Comment 2-02 above.

The text in Section 2.1.2 of the report has been modified to state that the type of container used to ship the spent IERs depends on a number of factors, including the mix of radionuclides in the material to be transported and the specific activity of the material. Additional information is also provided in Section 4.1.2.1, where it is noted that low specific activity spent IERs can be shipped as LSA material when certain criteria are met.

Also, the text in Section A.2.2 in Appendix A has been modified to further describe the different types of shipping containers and the factors that influence the choice of a specific type of container. Specific to the comment, the modified text presents the following three criteria that must be met for shipping spent IERs as LSA material:

- Average specific activity does not exceed one-ten thousandth of the  $A_2$  value per gram of material (10 CFR 71.4)<sup>10</sup>;
- External radiation from the shipping package must not exceed 0.1 millisieverts (mSv)/hour (10 mrem/hour) at 2 meters (m) (6.6 feet (ft)) (10 CFR 71.47(b)(3)); and
- The material must have an external radiation dose less than or equal to 10 mSv/hour (1 rem/hour) at a distance of 3 m (10 ft) from the unshielded material (10 CFR 71.14(b)(3)(i)).

These three criteria, taken together, demonstrate a "safety equivalency," where the external dose rate from a shipping package and the dose rate from the unshielded contents in the package are regulated to the same equivalent standards, regardless of whether the package is an industrial package or a Type A or Type B cask.

The revised text in Section A.2.2 also notes that, in some cases, a package of spent IERs that meets the LSA criteria, and can be shipped as LSA, can contain more than the  $A_2$  value. However, an industrial package carrying more than the  $A_2$  value must meet the 10 CFR Part 71 criteria for LSA cited above with regard to the external dose rates of the shipping container and unshielded material.

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<sup>10</sup> NRC Staff Note: For LSA-II material.

*In response to the comment, the staff agrees that, technically, an 8-120A cask and a 21-300 cask, each loaded to capacity with LSA material, could potentially contain up to 900 A<sub>2</sub> values and over 1,200 A<sub>2</sub> values, respectively. However, without additional information, the NRC cannot determine if such packages could actually be shipped as LSA, because the contents may fail to meet the regulatory criteria identified above for the dose rate limits for the loaded shipping containers or their unshielded contents.*

*The text in Section A.2.2 has also been modified to include justification for the assumption that all the spent IERs are shipped in Type A or Type B casks results in a more conservative analysis than assuming that some spent IERs are shipped as LSA in industrial packages. This assertion is directly tied to four primary factors detailed in Appendix A upon which potential environmental impacts of transporting spent IERs are based: (1) the total number of shipments (affects local and national traffic); (2) the radiation dose rate from the shipping container (affects radiation doses to members of the public from routine, incident-free transport); (3) the number of miles driven (affects the potential number of transportation accidents); and (4) the dose rate from unshielded material (affects the potential impacts from accidents in which the radioactive contents of shipping containers are released). Each factor is discussed below, to establish why the assumed use of only Type A and Type B casks for spent IER shipments is more conservative than using industrial packages for some shipments:*

- 1. Total number of shipments: Because Type A and Type B packages incorporate heavy shielding and Type B packages also have impact load limiters, the weight of Type A and B casks is higher than for industrial packages; and while more than one industrial package would be transported per truck shipment to optimize shipping, only one Type A or Type B cask can be transported per truck. Thus assuming the use of only Type A and B packages for spent IER transport results in the estimation of more shipments and, therefore, greater potential impacts on local and national traffic, than would be estimated when using smaller, lighter industrial packages for some shipments.*
- 2. Dose rate from the shipping container: By regulation, the maximum allowable dose rate on the outside of the shipping container is the same for LSA, Type A, and Type B packages, i.e., 0.1 mSv/hour (10 mrem/hour) at 2 m (10 CFR 71.47(b)(3)). Because the external package dose limit is the same for all three package types (i.e., LSA = Type A = Type B), and there will be more shipments if using only Type A and Type B casks (see above), the estimated population dose is increased by the assumption that all shipments are in Type A and Type B casks.*
- 3. Number of miles driven: Since assuming the use of only Type A and B packages results in the estimation of more shipments and, therefore, more miles driven than would be estimated when using industrial packages for some shipments, it follows that the more miles that are driven, the more potential transportation accidents could occur.*
- 4. Dose rate from unshielded material: In Section A.3.3.2.2, the dose to the maximally exposed member of the public is calculated, based on a transportation accident that releases the entire A<sub>2</sub> quantity of spent IERs from a Type A cask. In this accident scenario, the estimated dose to the member of the public of 1.11 mSv (111 mrem) is*

*based on a 10-hour exposure, at 30 m, to an unshielded A<sub>2</sub> quantity of spent IERs (see Table A-19). If instead of a Type A cask with an A<sub>2</sub> quantity, the contents of an industrial package carrying spent IERs as LSA were released, the dose to a member of the public would be lower, at 1 mSv (100 mrem).<sup>11</sup>*

**Comment 2-19B:** Third, the evaluation fails to consider that the vast majority of the curies shipped in Class B and C wastes currently benefit from the protections afforded by shipment in Type B casks, which are designed to withstand accident conditions. In a downblending scenario, a significant amount of radioactivity will be dispersed into a large number of shipments that do not benefit from the protections afforded by robust Type B packaging. It should also be expected that market forces will drive the average curie content of the myriad Class A shipments to the very limits of radioactivity of that waste class, and to the limits of Type A cask capacity. Well-blended materials may not even require casks at all, but might be transported as LSA-II in shipper self-certified IP-2 packages as described above. In a disposal alternative, this huge curie inventory benefits from the additional transportation protections provided by Type B casks. In the processing alternatives, the risk is diluted and spread over myriad shipments, and the level of protection provided to any given curie in transportation is effectively reduced.

**NRC Response:** *Compliance with the NRC radioactive materials packaging and transportation regulations in 10 CFR Part 71 ensures that transport of spent IERs, pre- or post-blending, is equally safe if shipped as LSA in industrial packages or shipped as non-LSA material in Type A or Type B casks. The NRC cannot predict market forces or their effects on the average curie content of the Class A spent IER shipments or on Type A cask availability for these shipments. The NRC disagrees with the commenter's characterization of the numbers of shipments in the processing alternatives as "myriad," in comparison to the numbers of shipments in the other alternatives. No change was made in response to this comment.*

### **Comments 2-20A and B: Annual Number of Truck Shipments**

**Comment 2-20A:** The evaluation apparently assumes that the net total resin shipments will reflect only the current volume of Class A, B, and C resin shipments from nuclear power plants, and that the plants themselves will provide sufficient Class A resin material to support effective downblending. The basis of this assumption is not evident, and the industry generally presumes that Class A resins from other sources (e.g. public water treatment facilities) will be needed as 'feedstock' to affect downblending to Class A. If this is the case, many more Class A shipments of Class A feedstock will be required to support downblending. Since these materials are currently direct-disposed as wastes, their shipment to a central processing facility necessarily doubles the required transportation and associated risk, not considered in the current evaluation.

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<sup>11</sup> **NRC Staff Note:** *This dose to a member of the public is based on the following: The regulatory maximum dose rate for unshielded LSA is 10 mSv/hour @ 3 m (10 CFR 71.14(b)(3)(i)). Thus, 10 hours of exposure at 3 m gives a dose of 100 mSv at 3 m. Then, to calculate what this dose of 100 mSv at 3 m would be at 30 m, since dose is inversely proportional to the square of the distance from the source, 100 mSv is multiplied by the ratio of squares of the distances (3 m and 30 m). The dose for 10 hours of exposure @ 30 m =  $[(3 \times 3) / (30 \times 30)] \times 100 \text{ mSv} = 1 \text{ mSv}$ .*

**NRC Response:** *For reasons discussed in the response to Comment 2-02 above, the NRC staff's intent in Option 2 of SECY-10-0043 (NRC, 2010a) was that the comparative environmental evaluation would be conducted for alternatives for managing spent IERs from NPPs, including blending. As also discussed, Option 2 did not specify that the staff should study the technical or economic feasibility of implementing any of the alternatives. Thus, the evaluation was not required to, and therefore did not include a determination of whether additional shipments of Class A spent IERs would be required from non-NPP facilities to provide sufficient low-activity feedstock to accomplish the blending. Therefore, the impacts of additional shipments of Class A spent IERs from sources other than NPPs were not considered in the evaluation and no changes were made as a result of this comment.*

**Comment 2-20B:** WCS also notes that the evaluation does not consider the finite availability of Type A and Type B shipping casks. Alternatives featuring treatment increase the number of transport evolutions, and correspondingly increase the demand for cask use (approximately doubling the number of required shipments). Limited cask availability therefore seems likely to force resin processing facilities to store treated resins on site for extended periods. Extended storage of waste by generators is contrary to the longstanding official position of the NRC. The evaluation should consider the public dose and environmental impacts of extended storage at the processing facilities made necessary by the limited availability of shipping casks. In addition, the limited cask availability owing to increased demand from extra trips to the processing may result in an inadvertent extension of resin storage at the nuclear power plants (a delay that does not occur in direct disposal alternatives). It should also be noted that the companies that benefit most from the downblending process own and control most of these casks, which could cause further disruption of their availability for the preferred direct disposal option.

**NRC Response:** *Although not specifically stated in the Draft Report, the evaluation was based on an underlying assumption that there would be sufficient numbers of Type A and Type B shipping casks to implement each of the alternatives in accordance with their descriptions. This assumption and its effect on the evaluation have now been added to the discussion in Section 3.1.2 of the report. If in actual practice there was, in fact, a shortage of Type A and Type B casks, some of this shortage could be offset by using industrial packages for shipments that could be classified as LSA, which as indicated by the commenter in Comment 2-19A above and agreed by the NRC staff, are already in use for shipping some Class A resins.*

*The assumption that sufficient numbers of shipping casks would be available is reasonable for the generic, non-location-specific evaluation, because it would be too complex to evaluate the potential impacts of several additional possible actions within each of the alternatives, such as extended storage—for different periods of time—of untreated spent IERs at the NPPs, of untreated or treated spent IERs at the processing facility, and of treated spent IERs at the disposal facility. Also, this assumption results in conservative estimates of potential environmental impacts, considering that if alternatives were instead assumed to be implemented over extended periods of time due to cask shortages, the annual numbers of truck shipments and associated potential transportation impacts on an annual basis would be reduced. Finally, in a generic evaluation, the staff can make no assumptions or conclusions regarding which companies control the shipping casks, how these casks may be used in actual practice, and the ability of other companies to fabricate or purchase additional casks.*

### B.2.3 Commenter 3—Rusty Lundberg (Utah Department of Environmental Quality, Division of Radiation Control (DRC))<sup>12</sup>

**Comments 3-01A and B: Disposal Need**—the document may understate the need for shallow land disposal of SIER<sup>13</sup> in the U.S. for at least 2 reasons.

**Comment 3-01A: Number of Nuclear Reactors Without Class B/C Disposal Access**—the NRC document (p. viii) states that 40 of 65 operating NPP in the U.S. have no disposal access for Class B and C low-level radioactive waste (LLRW); indicating 61.5% of the industry lacks disposal access. However, when considering many domestic NPP stations have more than 1 reactor at their site, the problem is actually larger. Prior to July, 2012<sup>14</sup>, 85 of the 104 operating U.S. nuclear reactors (or ~82%) did not have Class B-C disposal access, see Attachment 1<sup>15</sup>. [NRC Staff Note: Attachment 1 has not been reproduced in this appendix, but is available in ADAMS in the commenter's original comment transmittal, under ADAMS Accession Number ML13025A354.]

**NRC Response:** *The comment is noted. However, when preparing the Draft Report, the NRC staff intentionally chose to express the problem in terms of number of NPPs rather than number of nuclear reactors, because staff believes that the general public would be more familiar with the concept of numbers of power plants than numbers of reactors. In that context, it was correct that, as stated in the Draft Report, more than 40 of the 65 operating NPPs in the U.S. had no disposal access for their Class B and C spent IERs. This approach did not result in an understatement in the report of the need for shallow land disposal of spent IERs in the U.S. Therefore, no change has been made to the report as a result of this comment. However, as discussed in the response to Comment 2-08 above, the report has been revised to recognize that WCS can accept out-of compact Class A, B, and C LLRW for disposal (subject to annual limits and case-by-case import petition approval by the Texas Compact), and that all NPPs potentially have access to a disposal facility for their Class B and C spent IERs at this time.*

**Comment 3-01B: Relative Resin Volume and Activity in NPP LLRW**—recent research conducted by the Electric Power Research Institute (EPRI) of LLRW manifests records, taken from the DOE MIMS<sup>16</sup> database, for 4 years (2003–2006), of LLRW waste shipments from 41 NPP sites (or 65 reactors), found that SIER waste constituted about 9% (~257,000 ft<sup>3</sup>) of the national LLRW volume generated, yet represented about 79% (~63,240 Ci<sup>17</sup>)<sup>18</sup> of the annual

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<sup>12</sup> NRC Staff Note: A list of references provided by the commenter has not been reproduced in this appendix, but is available in ADAMS on page 6 of 6 of the commenter's original comment transmittal, under ADAMS Accession Number ML13025A354.

<sup>13</sup> NRC Staff Note: SIER = spent ion exchange resins.

<sup>14</sup> NRC Staff Note: This footnote appears as footnote 2 in the comment: In July, 2012 the Texas LLRW Compact began approving import petitions for disposal of waste.

<sup>15</sup> NRC Staff Note: This footnote appears as footnote 3 in the comment: Attachment 1 is based on a November 6, 2012 presentation by Dr. Allison M. McFarlane, NRC Chairman (Slide 2) after comparison with current LLRW Compact membership. This membership map is available at: <http://www.nrc.gov/waste/llw-disposal/licensing/compacts.html>. (accessed 11/30/12).

<sup>16</sup> NRC Staff Note: DOE = U.S. Department of Energy; MIMS = Manifest Information Management System.

<sup>17</sup> NRC Staff Note: Ci = curie(s).

activity. Further, the EPRI study projected the industry-wide SIER generation, for 100 domestic reactors and estimated that national SIER annual output would be 90,620 ft<sup>3</sup>/yr<sup>19</sup> (volume) with a total activity of 43,800 Ci/yr<sup>20</sup>, see Table 1 below. Please note that these recent EPRI predictions of industry SIER output is only about 35% of those SIER quantities suggested in the 1981 NRC Draft Environmental Impact Statement for LLRW.<sup>21</sup>

Table 1. EPRI Projected Annual NPP Industry SIER Output<sup>22</sup>

Reactor Type / Design	National Annual	
	Volume ft <sup>3</sup> /yr <sup>23</sup>	Activity Ci/yr <sup>24</sup>
Boiling Water Reactors	53,600	30,600
Pressurized Water Reactors	37,020	13,100
Total:	90,620	43,800 <sup>25</sup>

**NRC Response:** As discussed in Section 2.1.3 of the report, the NRC staff used the EPRI study referenced by the commenter as the source of average annual NPP spent IERs volumes used in the evaluation. The projected annual NPP industry spent IER output of 90,620 ft<sup>3</sup> quoted by the commenter matches the quantity reported in Section 2.1.3. The staff would like to clarify that using data from DOE's MIMS database (as cited in Section 2.1.3 of the report), this 90,620-ft<sup>3</sup>/yr volume represents approximately 4 percent of the total volume of LLRW from all commercial generators in 2010 (2,146,000 ft<sup>3</sup>), including the NPPs. The report correctly characterizes the need for shallow land disposal of spent IERs in the U.S. The remainder of the information presented in the comment is noted, but is not directly relevant to the evaluation. As such, no change to the report was made because of this comment.

<sup>18</sup> NRC Staff Note: This footnote appears as footnote 4 in the comment: See Attachment 2. Resin percentages were calculated by DRC staff from information provided in the November, 2007, EPRI Report, Tables 6-4 and 6-5. [NRC Staff Note: The commenter's Attachment 2 has not been reproduced in this appendix, but is available in ADAMS in the commenter's original comment transmittal, under ADAMS Accession Number ML13025A354.]

<sup>19</sup> NRC Staff Note: ft<sup>3</sup>/yr = cubic feet/year.

<sup>20</sup> NRC Staff Note: Ci/yr = curies/year.

<sup>21</sup> NRC Staff Note: This footnote appears as footnote 5 in the comment: See 1981 NRC DEIS, Vol. 2, Table 3.4, specifically the sum of the 3 waste streams: P=IXRESIN; B=IXRESIN; and L=DECONRS.

<sup>22</sup> NRC Staff Note: This footnote appears as footnote 6 in the comment: November, 2007 EPRI report. This table is similar to Table 2 found in the 9/12 NRC SIER Evaluation Report.

<sup>23</sup> NRC Staff Note: This footnote appears as footnote 7 in the comment: Based on DRC addition of EPRI projected industry-wide resin volume data for Class A, B, and C LLRW, see November 2007 EPRI Report, Table 6-10.

<sup>24</sup> NRC Staff Note: This footnote appears as footnote 8 in the comment: See November, 2007 EPRI Report, Table 6-12.

<sup>25</sup> NRC Staff Note: This footnote appears as footnote 9 in the comment: Direct quote of industry-wide projection of total activity, see November, 2007 EPRI Report, Table 6-12.

**Comment 3-02: NRC Dependence on EPA Programs for Environmental Protection**

**(p. xvi, etc.)**—the NRC evaluation states (p. xvi<sup>26</sup>) that SIER handling, transport, processing, and disposal would not pose a threat to the environment, because of regulatory authority / permitting of the EPA National Pollutant Discharge Elimination System (NPDES) program. While at first glance, it would appear that EPA and/or its Primacy States would be able to use surface water quality regulations (i.e., NPDES rules) to protect public health and the environment, the document does not consider several key issues, namely:

- A. Purpose of the Atomic Energy Act (AEA)—from its onset, the purpose of the AEA was to place the responsibility for oversight of nuclear energy and protection of public health and the environment with the agency that is now known as the NRC. The document does not explain why the NRC should rely on, share, or defer its responsibility to the EPA (or Primacy States) to permit and inspect facilities that store, treat or dispose of SIER. In order to fulfill the intent of the AEA, it appears that NRC should develop all needed regulations, issue appropriate licenses, and fulfill inspections and compliance activities for SIER treatment, storage, and disposal facilities.
  
- B. Limitations in EPA Defined Water Quality Criteria for Alpha Emitters—EPA has promulgated only three (3) concentration-based surface water quality criteria (or standards) for protection of human health, namely: gross alpha, Ra-226+228, and Uranium<sup>27</sup>. These three are taken from EPA Drinking Water standards, discussed below. Of these three, radium isotopes should not be found in NPP SIER, having been eliminated from nuclear fuel during enrichment / fabrication. However, many alpha emitting nuclides, including U-235 have been identified by the Electric Power Research Institute (EPRI) as important or principle nuclides in LLRW and SIER, see Table 2, below. This research was based on EPRI review of the DOE MIMS database LLRW manifest forms for 4 years (2003 - 2006) from 41 NPP in the U.S (i.e., 65 different reactors).

Other information was also available for NPP SIER from NRC sources<sup>28</sup>, and has also been added to Table 2. Table 2 illustrates that 12 alpha emitting nuclides are known to exist in SIER, however, the EPA NPDES program would only have one surface water quality standard, gross alpha, to monitor for these. Hence, it is unclear if the NPDES program could effectively protect public health and the environment at SIER treatment, storage, or disposal facilities.

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<sup>26</sup> NRC Staff Note: This footnote appears as footnote 10 in the comment: This claim is made in many other locations in the document, e.g., pp.5-5, 5-53, 5-51, etc.

<sup>27</sup> NRC Staff Note: This footnote appears as footnote 11 in the comment: See EPA Water Quality Standards Handbook, 2<sup>nd</sup> Edition, March 2012, “Chapter 3 Water Quality Criteria (40 CFR 131.11)”, available on internet at: <http://water.epa.gov/scitech/swguidance/standards/handbook/index.cfm> (accessed November 23, 2012).

<sup>28</sup> NRC Staff Note: This footnote appears as footnote 12 in the comment: September, 2012 NRC SIER Evaluation, p. 2-2; and 1981 NRC Draft Environmental Impact Statement, Vol. 2, Table 3.3.

Table 2. EPRI and NRC Identified Isotopes in NPP LLRW and SIER Waste

Nuclides	Half-life		t1/2 < 100 yrs?	Decay Mode				
	t1/2	units		alpha?	beta?	gamma?	Other?	
<i>EPRI Identified as "Principal Nuclides" in LLRW (11/07 EPRI Table 6-1)</i>								
H-3	12.32	Yr	y	no	β-	no	no	
<b>C-14</b>	<b>5,715</b>	Yr	n	no	β-	no	no	
Co-60	5.27	Yr	y	no	β-	y	no	
<b>Ni-63</b>	<b>101</b>	Yr	n	no	β-	no	no	
<b>Tc-99</b>	<b>213,000</b>	Yr	n	no	β-	y	no	
Sr-90	28.78	Yr	y	no	β-	no	no	
Cs-137	30.07	Yr	y	no	β-	y	no	
<b>U-235</b>	<b>704,000,000</b>	Yr	n	α	no	y	no	
Pu-238	88	Yr	y	α	no	y	no	
Pu-239/240	<b>Pu-239</b> <b>Pu-240</b>	<b>24,100</b>	Yr	n	α	no	y	no
<b>Pu-241</b>	<b>375,000</b>	Yr	n	α	β-	y	no	
Am-241	<b>433</b>	Yr	n	α	no	y	no	
Cm-242	163	d	y	α	no	y	no	
Cm-243,244	<b>Cm-243</b>	29	Yr	y	α	no	y	ε
	<b>Cm-244</b>	18	Yr	y	α	no	y	no
<i>Other nuclides found in NPP SIER (11/07 EPRI Report, Table 6-12)</i>								
Cr-51	27.702	d	y	no	no	y	ε	
<b>Mn-54</b>	<b>312.1</b>	d	y	no	β-, β+	y	ε	
<b>Fe-55</b>	<b>2.73</b>	Yr	y	no	no	no	ε	
Fe-59	44.5	d	y	no	β-	y	no	
Co-57	271.8	d	y	no	no	y	ε	
<b>Co-58</b>	<b>70.88</b>	d	y	no	β+	y	ε	
<b>Ni-59</b>	<b>76,000</b>	Yr	n	no	β+	no	ε	
<b>Zn-65</b>	<b>243.8</b>	d	y	no	β+	y	ε	
Zr-95	64.02	d	y	no	β-	y	no	
<b>Nb-94</b>	<b>20,000</b>	Yr	n	no	β-	y	no	
Ag-110m	250	d	y	no	β-	y	no	
Sb-125	3	Yr	y	no	β-	y	no	
Cs-134	2	Yr	y	no	β-	y	ε	
Ce-144	285	d	y	no	β-	y	no	
<i>NRC Identified NPP SIER Nuclides, not listed above (see key below for data sources)</i>								
<b>Ba-133</b>	<b>10.53</b>	Yr	n	no	no	y	ε	
I-129	<b>15,700,000</b>	Yr	y	no	β-	y	no	
Cs-135	<b>2,300,000</b>	Yr	y	no	β-	no	no	
U-238	<b>4.47E+09</b>	Yr	y	α	no	y	no	
Pu-242	<b>375,000</b>	Yr	y	α	no	y	no	
Am-243	<b>7,370</b>	Yr	y	α	no	y	no	
<b>Count of Nuclides:</b>				<b>Count:</b>	12	33.3%	<b>(α emitters)</b>	
Total in SIER:		36		<b>Total:</b>	36			
Short-lived:		21 (t1/2 < 100 yrs)						
Long-lived:		15 (t1/2 > 100 yrs)						
<b>Key:</b>								
<b>bold</b>	= half-life, t1/2 > 100 yrs							
	= alpha emitting nuclide, possibly detected by gross alpha methods.							
	= may be significant in NPP SIER (see 9/12 NRC SIER Evaluation, p. 2-2)							
	= nuclides identified in NPP SIER (see 1981 NRC DEIS, Vol. 2, Table 3.3).							

- C. Complication in EPA Dose Standards for Human Health: Beta-Gamma Emitters—as seen in Table 2, 24 of the known NPP SIER nuclides are beta-gamma emitters. For these isotopes, the EPA NPDES program does set discrete water quality criteria (standards) for beta and photon emitting radionuclides. Instead, EPA sets an annual dose limit of 4 mR/yr<sup>29</sup>. In order to convert the EPA dose standard to an activity equivalent, isotope-specific dose conversion factors are required. The EPA NPDES rules do not dictate a specific methodology to guide the regulator in the selection of dose conversion factors that would determine compliance standards in surface water under a NPDES permit. In summary, the NPDES program relies on the EPA Safe Drinking Water Act and its rules to establish in-direct drinking water standards (DWS) and determine conversion factors for individual nuclides, to protect human health.

Closer review of the Safe Drinking Water (SDW) rules shows that only two of the SIER beta-gamma emitters have promulgated DWS activity limits, H-3 and Sr-90<sup>30</sup>. For the remaining 24 beta-gamma emitters, the 4 mR/yr dose standard applies. As for dose conversion factors, the EPA SDW rules rely on severely antiquated dose conversion factors be used to calculate equivalent water quality activity standards; namely the National Bureau of Standards Handbook 69, published in August, 1963<sup>31</sup>. These dose conversion factors are even older than those used by the NRC to establish the current occupational and effluent limits set in 10 CFR 20 rules [ICRP Publications 26 (1977) and 30 (1978)]<sup>32</sup>. These NRC limits are aimed at protection of NPP workers and the environment, and are not directly focused on direct human consumption (drinking water). Further, even more modern dose conversion factors have been published, based on more recent scientific research, see ICRP Publications 60 (1991) and 103 (2007)<sup>33</sup>. NRC should consider updating its 10 CFR 20 rules to reflect these modern advancements in dose conversion factors, and establish limits for direct human consumption.

Table 2 Sidenote: It is important to note in Table 2, that 15 of the 36 known SIER nuclides are long-lived. Of these 15 nuclides, 14 have half-lives in excess of 5,700 years. These very long-lived nuclides can pose significant challenges for long term waste management and LLRW disposal embankment performance. Many of these long-lived nuclides were identified as SIER components in the original NRC EIS that launched the US LLRW program<sup>34</sup>.

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<sup>29</sup> NRC Staff Note: This footnote appears as footnote 13 in the comment: Annual dose limit found in: 1) EPA Water Quality Standards Handbook, 2<sup>nd</sup> Edition, March, 2012, "Chapter 3 Water Quality criteria (40 CFR 131.11)", at: <http://water.epa.gov/scitech/swguidance/standards/handbook/index.cfm>, and 2) <http://water.epa.gov/drink/contaminants/index.cfm>.

<sup>30</sup> NRC Staff Note: This footnote appears as footnote 14 in the comment: See 40 CFR 141.66, Table A; where EPA DWS for H-3 (20,000 pCi/l) and Sr-90 (8 pCi/l) are set.

<sup>31</sup> NRC Staff Note: This footnote appears as footnote 15 in the comment: See 40 CFR 141.66(d)(2).

<sup>32</sup> NRC Staff Note: This footnote appears as footnote 16 in the comment: Federal Register Notice, Vol. 71, No. 13, January 20, 2006, p. 3343.

<sup>33</sup> NRC Staff Note: This footnote appears as footnote 17 in the comment: See ICRP Publication 103, p. 11 Extract available at: <http://www.icrp.org/page.asp?id=111>. (accessed 12/3/12).

<sup>34</sup> NRC Staff Note: This footnote appears as footnote 18 in the comment: September, 1981 NRC NUREG-0782, Volume 2, Table 3.3, waste streams P-IXRESIN and B-IXRESIN.

**NRC Response:** *In the Draft Report, the NPDES program was cited as an example of a Federal/State requirement that would serve to limit potential environmental impacts. For example, in Table 5, under Water Resources (Water Quality), NPDES requirements are cited as an example of a regulation that would limit discharges of liquid effluents. This does not mean that the NRC relies on, shares, or defers its responsibility under the AEA to the EPA (or Primacy States) to permit and inspect facilities that store, treat, or dispose of spent IERs. On the contrary, the NRC has developed all needed regulations, issues appropriate licenses, and fulfills inspections and compliance activities for spent IER treatment, storage, and disposal facilities (except where licensing, inspection, and compliance activities are appropriately delegated to Agreement States). However, where NPDES requirements were referenced as an example, the Draft Report did not include references to the NRC’s regulation in 10 CFR 20.1301, which requires NRC licensees to meet all-pathways dose limits to protect individual members of the public. Agreement-state licensees are subject to identical requirements imposed by the responsible Agreement State agency. In addition, both the NRC and Agreement State regulations specify that licensees subject to the provisions of EPA’s generally applicable environmental radiation standards in 40 CFR Part 190 shall comply with those standards.*

*The report has been modified to include the reference to 10 CFR 20.1301 where appropriate. This addition has been made in Table 5 under “Waste Management” and “Water Resources: Water Quality;” in Sections 5.1.2.6, 5.2.5, and 5.2.8; and under Public and Occupational Health and Waste Management in the Summary of Comparative Environmental Evaluation section of the Executive Summary. As discussed above, the existing references to NPDES are appropriate and have therefore been retained. The remainder of the detailed information presented in the comment is noted, but is not directly relevant to the generic evaluation.*

**Comment 3-03: Long-term Storage Under Alternatives 3 and 4A (pp. 3-3 to 3-4)**—both of these NRC alternatives call for a 20-year storage of Class B-C waste, after SIER treatment, and before any permanent land disposal.

- A. Utah Storage Prohibition—under NRC Alternative 4A, the NRC SIER evaluation makes mention of the possibility of long-term storage of Class B-C SIER at an existing LLRW landfill, that might be working on or awaiting issuance of a Class B-C license. Please note that commercial storage of Class B-C LLRW is currently prohibited in Utah by state statute<sup>35</sup>.
- B. Storage on Speculation—both options call for some type of 20-year "temporary" storage, be it at each NPP (Alternate 3), or at a central national location (Alternate 4A). However, both alternates depend on speculation that sometime in the future sufficient national Class B-C disposal capacity will be available, after NRC (or Agreement State) authorization of new landfills. It is unlikely that 20 years of storage will suffice. This is reinforced by the history of the US LLRW program, in that 30 years transpired since

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<sup>35</sup> NRC Staff Note: This footnote appears as footnote 19 in the comment: See Utah Code Annotated (UCA) 19-3-103.7.

issuance of the 1982 NRC Final EIS<sup>36</sup>, before any single Class B-C landfill was sited, licensed, and opened for operation (WCS facility in Texas). Consequently, NRC should possibly consider evaluating longer periods of time in its analysis.

**NRC Response:** *First, regarding the introductory statement made in this comment, the NRC staff would like to clarify that of Alternatives 3 and 4A, only Alternative 4A involves long-term storage of Class B and C concentration spent IERs after treatment (by volume reduction). In Alternative 3, the untreated Class B and C concentration spent IERs are stored at the NPPs for 20 years, and then shipped for disposal at the end of the long-term storage period.*

*Second, the staff notes the information on the Utah storage prohibition. However, this has no bearing on the generic, non-location-specific evaluation of the alternatives.*

*Third, in developing the evaluation, the staff considered a range of long-term storage periods (including periods shorter and longer than 20 years). The staff has considered evaluating longer periods of time (e.g., 30 years) in the analysis, but believes that the findings would not be significantly different for Alternatives 3 and 4A, and that the additional analysis would add little or no value. No change was made to the report as a result of this comment.*

**Comment 3-04:** HIC Headspace Requirements for Long-Term Storage: Utah's Need to Revisit CWF Design Basis (p. 4-8)—the NRC Evaluation states that empty head space is required in the High Integrity Containers (HIC), during long-term storage, to accommodate swelling of the SIER due to the absorption of water. Previous DRC engineering design review of SIER disposal at the Clive, Utah site is based on the stability of the waste form. Further, the approved engineering design basis for the Containerized Waste Facility (CWF), where this waste is disposed, requires each HIC have no more than a 15% internal headspace at the time of disposal. The NRC should consider providing references to technical literature where this swelling phenomenon has been documented.

**NRC Response:** *The reference in the report for information on spent IER swelling is (IAEA, 2002a), which was cited in Section 4.2.4 and included in the reference list (Section 6) of the Draft Report. A citation of this reference has been added in Section 4.2.4 where IER swelling due to water absorption is first mentioned.*

**Comment 3-05:** Control of Soil Impacts by EPA NPDES Program (p. 5-5, Table 5, etc.)—the NRC SIER Evaluation makes a statement in Section 5.1.2.6 that the NPDES program can be relied on to protect soil contamination near SIER storage / treatment facilities. This statement appears to over-estimate the authority of the NPDES regulations, which are designed to protect "waters of the United States", or in other words navigable or interstate waters<sup>37</sup>. While EPA or Primacy State permits may govern construction and operation of facilities that potentially discharge pollutants, the program's mission is to protect water resources, and not soils or

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<sup>36</sup> NRC Staff Note: This footnote appears as footnote 20 in the comment: NRC NUREG-0945, published in November, 1982.

<sup>37</sup> NRC Staff Note: This footnote appears as footnote 21 in the comment: See EPA rules in 40 CFR 122.1(b) and 122.2.

groundwater. Groundwater protection has its regulatory foundation in state law and regulation. This comment also applies to NRC Table 5 (pp. 5-34 to 35).

**NRC Response:** *NPDES requirements would also be protective of soil by limiting soil contamination from stormwater discharges over land. This has been clarified in Section 5.1.2.6 (Soil Impacts), where it is now indicated that it is the NPDES stormwater requirements that would help reduce, control, or avoid soil impacts. NPDES requirements were not mentioned under Soil in Table 5 in the Draft Report, and no change has been made in this regard in the Final Report. In addition, NRC regulations in 10 CFR, 20.1301 would apply, as discussed in the response to Comment 3-02 above.*

**Comment 3-06:** Pollution Prevention via Application of EPA NPDES to SIER Treatment, Storage and Disposal Facilities (p. 5-51)—reference is made that liquid effluents would not pose a hazard to human health or the environment due to the application of the EPA NPDES regulations, which would be done thru permit issuance and compliance activities conducted by EPA or Primacy States. We believe this claim may overstate the ability and regulatory authority of the EPA or Primacy States to oversee SIER related facilities and operations. Please refer to Comment 2, above [NRC Staff Note: this is Comment 3-02 above]. EPA regulation of SIER facilities may not involve design / construction review, nor compliance monitoring as it relates to most of the nuclides known to be present in SIER materials, because AEA-regulated facilities are essentially exempt from regulation under the Clean Water Act.

**NRC Response:** *See response to Comment 3-02 above.*

#### **B.2.4 Commenter 4—Joseph DiCamillo (Studsvik, Inc.)**

**Comment 4-01:** Studsvik supports the conclusions reached in the Comparative Environmental Evaluation. Studsvik suggests that an additional case be added to the evaluation to reflect current industry practices. Namely, volume reduction of Class A, B, and C Concentration spent IERs at a Processing Facility, then Disposal. Perhaps this case could be Alternative 4C. While Studsvik does not believe that this case will in any way alter the conclusions of the report, Studsvik believes that the report should identify, discuss and analyze all scenarios.

**NRC Response:** *The NRC staff notes this comment and has considered the commenter's suggestion to add an additional alternative to the evaluation to reflect "current industry practices." However, the additional alternative suggested by the commenter cannot be included in the report because it is not consistent with the alternatives specified in Option 2 of SECY-10-0043 (NRC, 2010a), which defined the scope of the evaluation (see response to Comment 2-02 above). No change was made to the report as a result of this comment.*

#### **B.2.5 Commenter 5—Thomas Magette (EnergySolutions, Inc.)**

**Comment 5-01:** In general we agree with NRC staff's conclusion that there are no significant impacts from the management of spent ion exchange resins, including those that involve blending. We further agree that impacts from all alternatives considered are in almost all cases low. We appreciate the staff's efforts to thoroughly address concerns that have been raised

regarding the potential environmental issues associated with blending ion exchange resins. As staff has demonstrated with its conservative, bounding analysis, the environmental impacts associated with this waste management strategy are inconsequential.

**NRC Response:** *The NRC staff notes the comment. No change was made to the report as a result of the comment.*

**Comment 5-02:** Attached are several detailed comments for your consideration. While we believe that these comments merit consideration and may result in minor editorial revisions, none are sufficiently significant to challenge the conclusions staff has reached. We do not believe that any additional analyses or significant revisions to the report are necessary.

**NRC Response:** *The commenter's detailed comments and NRC's responses to these comments are presented below.*

**Comment 5-03:** page viii - IERs are "bead-like materials." A significant portion is powdered material (pressure-precoat systems). There is also no mention of the frequent addition of activated charcoal to resin beds.

**NRC Response:** *The NRC staff agrees with this comment. The Introduction and Purpose section of the Executive Summary and Sections 1 and 2.1.1 of the report have been modified as appropriate to reflect the additional descriptive information provided in the comment.*

**Comment 5-04:** page viii - last paragraph refers to one licensed disposal facility as being authorized to accept Class A waste from all 50 States. This appears to be a reference to Clive, which while strictly speaking is true, does not correctly portray the situation. The Rocky Mountain and Northwest Compacts have a site that they are required to use. The Northwest Compact can authorize waste from that compact to go to Clive, but that is not the norm.

**NRC Response:** *The report has been modified to clarify that the Clive facility could accept LLRW from all 50 states, but the Rocky Mountain and Northwest Compacts require their generators to send Class A LLRW to the licensed LLRW disposal facility in the Northwest Compact. This clarification has been made in footnote 1 in the Introduction and Purpose section of the Executive Summary, footnote 7 in Section 1, and Section 2.2. This clarification does not change a key point in the report, that NPPs in all 50 states have access to an LLRW disposal facility for their Class A spent IERs.*

**Comment 5-05:** page xi - Thermal processing options will result in increased air emissions of radionuclides which are not normally removed from stack flow by mechanical filtration (e.g., <sup>14</sup>CO<sub>2</sub> and tritium). These emissions can be controlled within established limits, but arguably present higher radionuclide releases than mechanical blending.

**NRC Response:** *The NRC staff appreciates the clarification. However, the report has not been modified because only very general information is presented in the report on how air emissions may be controlled, and the staff believes the current description is sufficient to support the evaluation.*

## **Comment 5-06A, B, and C: page xiii – Transportation**

Comment 5-06A: The Transportation summary states that all resins are assumed to be transported over-the-road in Type A or Type B shipping casks. Note that resins meeting the definition of LSA material may be shipped in Industrial Packaging (see 49 CFR 173.427, Table 6). Current practices include disposition of significant quantities of very low activity Class A resins shipped by truck in 100 ft<sup>3</sup> metal boxes and sometimes metal drums. Less than half of the resins shipped to Bear Creek arrive in Type A or B casks.

**NRC Response:** *See response to Comment 2-19A above.*

Comment 5-06B: In addition, final disposition of these very low activity resins can include non-Class 7 shipments to local industrial landfills, rather than subsequent transfer to one of the four licensed disposal sites.

**NRC Response:** *The NRC staff appreciates the clarification. The general information in the comment has been added to the discussions of LLRW disposal facilities in footnote 6 in Section 1 and footnote 12 in Section 2.2 of the report. The analysis of transportation impacts in the report assumes that, in each alternative, all spent IERs are ultimately transported along representative routes to a single Class A or a single Class B and C disposal facility (see assumption in Section 3.1.2). Therefore, the identification of industrial landfills as a disposal option for very low activity spent IERs does not change the analysis.*

Comment 5-06C: It is also important to note that rail transport of wastes has displaced significant fraction of the over-the-road transport (particularly from Oak Ridge, TN, to Clive, UT).

**NRC Response:** *The NRC staff appreciates the clarification, and the text in Section 3.1.2 has been modified to indicate that transport of some portion of the untreated and treated spent IERs and of returned empty casks could be by rail.*

**Comment 5-07:** page 1-2 - Next to last paragraph states that resins must be replaced when their ion exchange capability is expended. Many of these resins can be regenerated, and some existing nuclear power plants (NPPs) were built with the capability to do so. In most NPPs, the practice has been found to be economically inefficient, with resulting waste problematic for disposal. This is, however, an additional processing option for generators, but one that is not addressed to any significant extent in this document.

**NRC Response:** *The NRC staff appreciates the additional information. Regeneration of IERs is discussed in Section 2.1.1 of the report. However, this process is not further discussed in the report because it is not one of the alternatives specified in Option 2 of SECY-10-0043 (NRC, 2010a) for consideration in the comparative environmental evaluation (see response to Comment 2-02 above).*

**Comment 5-08:** page 1-3 - As on page vii, the second paragraph on this page states that one licensed disposal facility is authorized to accept Class A waste from all 50 States. This appears to be an incorrect reference to Clive, which is *not* authorized to accept waste from the Rocky Mountain or Northwest Compacts.

**NRC Response:** See response to Comment 5-04 above.

**Comment 5-09:** page 2-1, section 2.1.1, Ion Exchange Resin Composition and Use. This section introduces IERs as "typically bead-like...", and should also note the widespread use of powdered resins (e.g., Graver Powdex systems).

**NRC Response:** See response to Comment 5-03 above.

**Comment 5-10:** page 2-1, section 2.1.2, Spent IER Generation and Management. This section states that spent IERs are sluiced to HICs or appropriate liners, which ignores the intermediate use of a spent resin storage tank. These tanks may be sized to accommodate resins from multiple resin beds, and can effectively result in commingling at the NPP sites. This has the same net effect as blending by an offsite processor.

**NRC Response:** The NRC staff appreciates the additional information. A footnote has been added in Section 2.1.2 of the report, which indicates that some NPP sites have a tank for holding spent IERs, and that spent IERs of differing concentrations may be mixed in such tanks as part of normal operations. However, the staff does not believe that this comingling of spent IERs has the same net effect as blending by an offsite processor. The offsite mechanical and thermal blending processes described in Alternatives 1A and 1B, respectively, would use equipment and procedures designed to effectively blend Class A, B, and C concentration spent IERs to create final homogeneous waste forms that would meet Class A concentration requirements. The NPP spent IER storage tanks were not designed to create uniform resin mixtures. No changes were made to the report as a result of this comment.

**Comment 5-11:** page 2-4, last paragraph. Another reference to Clive accepting Class A waste from all 50 States that needs to be corrected.

**NRC Response:** See response to Comment 5-04 above.

**Comment 5-12:** page 2-5, 1<sup>st</sup> paragraph states that processors may "take title" to B and C wastes, then thermally process the wastes for long term storage at another location pending availability of disposal. This statement oversimplifies the waste attribution considerations applicable to processors. These considerations are Compact-driven, and generally require explicit treatment in the licensing process.

**NRC Response:** The statement in Section 2.2 of the report regarding a LLRW processing company "taking title" to the Class B and C concentration spent IERs has been removed from the report.

**Comment 5-13:** page 3-3, Alternative 2. This direct disposal option assumes that NPPs perform handling (including dewatering), final packaging, and shipment to the LLRW disposal site. It should be noted that the NPP will need appropriate shielded process areas, dewatering equipment, and (most importantly) a process control plan to ensure the final IER package meets the water content limits. This can be addressed in detail in Section 4.

**NRC Response:** *The comment is noted. However, the additional information will not be added to Section 4 of the report because the NRC staff believes the descriptions of spent IER handling, packaging, and offsite shipment in Section 4.1 are sufficient to support the evaluation. Further, as discussed in Section 3.2, the evaluation assumes that no new spent IER storage, handling, processing, and disposal facilities will be constructed (with the exception of the long-term spent IER storage facilities considered in Alternatives 3 and 4A) and that all existing facilities operate under licenses from the NRC or Agreement States, which means the evaluation assumes that required infrastructure--such as appropriate shielded areas, equipment, and process control plans--would already be in place for each of the alternatives.*

**Comment 5-14:** page 3-3, last paragraph. For Alternative 4A (thermal volume reduction of B&C concentrations IERs by a processor, long-term storage, then disposal). Using the stated VR<sup>38</sup> factor of 5, spent IERs should be limited to those with concentrations < 20 % of the Class C limit (volume concentration based limits, Ci/m<sup>3</sup>)<sup>39</sup> to avoid generating > Class C waste. Similar constraints are needed for alpha-emitting TRU<sup>40</sup> nuclides (with half-life >5 years), <sup>241</sup>Pu, and <sup>242</sup>Cm subject to specific activity limits (nCi/g)<sup>41</sup>. Details are appropriate for Section 4, but the limitation should be mentioned here. In addition, a VR of 5 may shift materials from Class B to Class C, with associated disposal restrictions and increased disposal cost.

**NRC Response:** *The NRC staff appreciates the additional information. The descriptions of Alternative 4A in Sections 3.1.1 and 4.2.5 of the report have been modified to indicate that an average volume reduction factor of 5 to 1 is assumed, and the volume reduction facility would control the process to ensure that the final waste forms do not exceed Class C limits.*

**Comment 5-15:** page 3-3, 2nd paragraph. The same considerations noted in #12 [NRC Staff Note: this is Comment 5-14 above], above, concerning volume reduction apply to Alternative 4B, as well.

**NRC Response:** *Since the descriptions of Alternative 4B in Sections 3.1.1 and 4.2.6 of the report state that Alternative 4B is similar to Alternative 4A, and since no discussion of the volume reduction factor is included in those descriptions, no changes have been made to the report in response to this comment.*

**Comment 5-16:** page 4-1, paragraph 4.1.1, Dewatering of Spent IERs. Many NPPs lack available space, equipment and validated process control plans (frequently held as processor proprietary information) to conduct final dewatering for disposal. In addition, some resins require additional pre-treatment to reduce gas generation resulting from biological contamination of the IER. This treatment requires additional processing equipment and time. It should also be noted the IERs with significant iron oxide content become very difficult and time consuming to dewater. We do not propose that the analysis be revised to accommodate these exceptions, but they should be noted as limitations on the applicability of on-site final dewatering by NPPs.

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<sup>38</sup> NRC Staff Note: VR = volume reduction.

<sup>39</sup> NRC Staff Note: Ci/m<sup>3</sup> = curies/cubic meter.

<sup>40</sup> NRC Staff Note: TRU = transuranic.

<sup>41</sup> NRC Staff Note: nCi/g = nanocuries/gram.

**NRC Response:** *The comment is noted. However, the additional information will not be added to Section 4.1.1 of the report because the NRC staff believes the description of spent IER dewatering in this section is sufficient to support the evaluation. Further, as discussed in Section 3.2, the evaluation assumes that no new spent IER storage, handling, processing, and disposal facilities will be constructed (with the exception of the long-term spent IER storage facilities considered in Alternatives 3 and 4A) and that all existing facilities operate under licenses from the NRC or Agreement States, which means the evaluation assumes that required infrastructure—such as that identified in the comment—would already be in place for each of the alternatives.*

**Comment 5-17:** page 4-3, paragraph 4.1.3, Disposal of Untreated and Treated Spent IERs. This section states that all untreated and treated spent IERs will ultimately be disposed at licensed LLRW facilities. A significant quantity of very low activity resins is disposed at unlicensed industrial landfills. This could be classified as an additional disposal alternative.

**NRC Response:** *See response to Comment 5-06B above.*

**Comment 5-18:** page 4-4, last paragraph. This section should note that a process option for liquid from the dewatering step is necessary. Although gross dewatering may occur at NPP site prior to shipment to a processor, additional contaminated water is removed to prepare the IERs for disposal. This is in addition to the recycled water associated with routine sluicing operations.

**NRC Response:** *The NRC staff appreciates the additional information. Section 4.1.1 of the report identifies the 10 CFR 61.56(b)(2) requirements to dewater the spent IERs prior to disposal. The staff believes that the current description of spent IER dewatering in the report is sufficient to support the evaluation. No change was made to the report as a result of this comment.*

**Comment 5-19:** page 4-6, 3rd paragraph. This section states that thermal processing produces essentially no secondary solid wastes. As noted in the process description, ceramic filters are used in two stages of processing, along with HEPA filtration of the final offgas. In addition, contaminated waste salts are produced from acid gas neutralization and dewatering filters (used by NPPs to conduct the initial gross dewatering) and must be properly disposed, along with any shipping containers not reused for burial shipment. In summary, the thermal process does produce substantial secondary waste.

**NRC Response:** *The NRC staff appreciates the additional information. The generation of incidental wastes had already been noted in the description of Alternative 1B in Section 4.2.2 of the Draft Report. However, Section 4.2.2 has been modified to indicate that these incidental wastes, which include ceramic filters, HEPA filters, and contaminated salt wastes, and are relatively small in volume when compared to the volume of materials processed. Also, as was noted in the Draft Report and again in the Final Report, these incidental wastes contain less than one-half of one percent of the incoming radioactivity. (Mason et al., 1999; THOR<sup>SM</sup>, 2006) For these reasons, the staff does not find these wastes to be “substantial,” as indicated in the comment.*

**Comment 5-20:** page 4-6, Alternative 2, Direct Disposal of Class A, B, and C Spent IER LLRW. This very brief entry for this Alternative should acknowledge considerations described above in comment #14 [NRC Staff Note: this is Comment 5-16 above].

**NRC Response:** *The additional information on dewatering of spent IERs at NPPs described in the commenter's referenced comment is not appropriate for inclusion in Section 4.2.3 of the report, which describes Alternative 2, as dewatering is already appropriately addressed in Section 4.1.1. See also the response to Comment 5-16 above regarding including additional information on dewatering in Section 4.1.1.*

**Comment 5-21:** page 4-8, paragraph 4.2.5, Alternative 4A. We do not find this alternative to be credible or realistic. Storage of processed waste at disposal and processor sites is strictly controlled and long-term storage of waste is prohibited by license. Although it was recently done at the Texas Compact site, regulators in Texas have objected to its becoming a common practice and it is not likely to be repeated. Rather than investing effort to remove or reanalyze this alternative, we propose that its practical limitations simply be noted.

**NRC Response:** *The comment is noted. While some license restrictions may apply for a licensee, the analysis in this report is not tailored to specific license conditions. This report is a generic environmental evaluation of alternatives for handling low-level radioactive waste spent ion exchange resins and staff believes that Alternative 4A is a valid scenario for evaluation. Accordingly, Alternative 4A has been retained for consideration in the evaluation and no change was made to the report as a result of this comment.*

**Comment 5-22:** page 5-9, 1<sup>st</sup> paragraph. For reference and comparative risk evaluations, an outdated baseline "U.S background dose" is cited as 360 mrem/y,<sup>42</sup> using data from the 1998 3<sup>rd</sup> edition of Handbook of Health Physics and Radiological Health, Schleien, et al. That data is based upon information from the NCRP Report #93,<sup>43</sup> Ionizing Radiation Exposure of the Population of the United States, published in 1987. The data set has been updated in NCRP Report #160, Ionizing Radiation Exposure of the Population of the United States, published in 2009. The reference value has been revised upward to 620 mrem/y, mostly attributable to increased use of CT<sup>44</sup> scans as a diagnostic tool. Note that the use of the term "U.S. background dose" may be somewhat misleading, as the values in both reports are the average exposures to the U.S. population from all sources. The effect of the nominal 70% increase in average exposure is the commensurate reduction in relative risk when transportation-related doses are compared to the average annual dose from all sources.

**NRC Response:** *This comment has given the NRC staff reason to reconsider the U.S. average annual background dose used for comparison purposes in the evaluation. The reported "background dose" has changed over time. U.S. background dose was assessed by the NCRP in 1987 as 3.6 mSv per year, of which 83 percent (3.0 mSv per year) was categorized as "natural" and included doses internal to the human body, and the remainder was from "artificial"*

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<sup>42</sup> NRC Staff Note: y = year.

<sup>43</sup> NRC Staff Note: NCRP = National Council on Radiation Protection & Measurements.

<sup>44</sup> NRC Staff Note: CT = computed tomography.

sources including medical procedures, consumer products, and other sources (NCRP, 1987). Although the NCRP was careful to identify natural background radiation and distinguish it from other sources, after 1987 the U.S. average annual background dose was usually cited (e.g., in NRC reports) as 3.6 mSv per year, the sum of the natural and artificial components. In 2009, the NCRP re-evaluated the annual U.S. background dose and concluded that, while average annual U.S. background radiation from natural sources had increased only slightly, from 3.0 to 3.11 mSv, the average annual exposure to other sources (primarily medical procedures) had increased approximately five-fold, from 0.6 mSv per year to 3.1 mSv per year (NCRP, 2009), for a total of 6.2 mSv per year (620 mrem per year) as noted by the commenter. The increase in the artificial contribution to “background” has resulted in different interpretations by different analysts of what background is, i.e., whether or not it should include the artificial component.

For this evaluation, the staff has decided to use the average background dose of 3.11 mSv per year (311 mrem per year) from natural sources only (NCRP, 2009) for comparison with estimated doses in the report, because this is more conservative than using higher background values that include artificial contributions and because doses to members of the public from artificial sources of radiation are highly variable. Consequently, revised discussions regarding background dose are presented in the Final Report in Sections A.1.1 (footnote 2), A.3.2, 5.1.2.1.1 (footnote 22), and 5.1.2.7.2, and under Transportation in the Summary of Comparative Environmental Evaluation section of the Executive Summary (footnote 6). In addition, comparisons with background where they appear in tables and corresponding text in Appendix A have been re-calculated by substituting the U.S. average annual natural background value of 3.11 mSv per year for the traditionally cited value of 3.6 mSv per year used in the Draft Report. The comparisons of radiation dose from the spent IER shipments with U.S. average annual background radiation shown in Tables A-7, A-8, A-11, A-14, A-17, A-19, and A-22 remained the same in most cases, because they were appropriately cited to only one or two significant figures and are very small numbers. The changes that did occur were very small to negligible in magnitude. The changes in the tables resulted in minor changes to the text describing the comparisons with background in the tables, in Sections A.3.2.1.2, A.3.2.3.1, A.3.2.3.2, A.3.3.2.1, and A.3.3.2.2. These changes are also reflected where appropriate in the main report, under “Transportation: Routine (Incident-free) – Radiological (Individuals and Populations)” and “Transportation: Accidents – Non-radiological and Radiological” in Table 5 and in Sections 5.2.7.2 and 5.2.7.3 and the corresponding sections in the Executive Summary.

**Comment 5-23:** page 5-13, Accidents in Which a Type A Cask Would Be Impacted. As noted in Comment #4, above [NRC Staff Note: this is Comment 5-06A above], resins meeting LSA-2 criteria may be shipped in IP-2 packages, rather than Type A or Type B casks. Shielded overpack containers may be used to meet restrictions on radiation levels.

**NRC Response:** See response to Comment 2-19A above.

**Comment 5-24:** page 5-28, Table 5, Comparison of Potential Environmental Impacts of the Six Alternatives..... Assessing the potential impacts of Alternatives 3 and 4A (both long-term storage scenarios) on Historic and Cultural Resources as “small to moderate” appears unduly conservative. Given the acknowledged small footprint required for storage and the thorough

environment siting process for NPPs and disposal sites, it is highly unlikely that there would be any impacts from these alternatives that could not be easily avoided or fully mitigated. We recommend the potential impacts of alternatives 3 and 4A be revised downward to "small."

***NRC Response:*** *In this evaluation, the NRC staff's findings for Alternatives 3 and 4A were based on known cases in actual practice in which impacts to historic and cultural resources that could perhaps have been avoided were instead mitigated. However, the text in Table 5 does acknowledge that due to the small sizes of the new storage facilities (as described in Sections 4.2.4 and 4.2.5, respectively), impacts could likely be avoided. NRC staff elected to include the more conservative assumption that mitigation of adverse effects might be employed, in which case the impact could be MODERATE. No changes have been made to the report in response to this comment.*

**Comments 5-25A and B:** page 5-49, paragraph 5.2.7.2

Comment 5-25A: dose should be updated to reflect currently available information. The result will be reductions in the already extremely low relative risk data presented.

***NRC Response:*** *See response to Comment 5-22 above.*

Comment 5-25B: Analyses do not consider use of Industrial Packagings in addition to Type A and B casks.

***NRC Response:*** *See response to Comment 2-19A above.*

#### **B.2.6 Commenter 6—Michael Dooley (Phoenix Energy of Nevada, LLC and Kurion, Inc.)**

[NRC Staff Note: A portion of the comment package from Commenter 6 is reproduced below. The entire 48-page comment package is available in ADAMS, under ADAMS Accession Number ML13092A456. The package presents descriptive and design information for the Phoenix Energy of Nevada, LLC and Kurion Inc. "Skid Mounted Transportable Nuclear Power Plant On-Site Spent Ion Exchange Resins Class B/C Driver Radioactive Isotopes Stripping and Transfer and induction Heat Melt Volume reduction Modular Vitrification System Low Level Radioactive Waste Processing and Storage Systems Facility."]

**Comment 6-01:** Phoenix Energy of Nevada, LLC (PENV), a power and energy engineering, design and construction Company, and Kurion, Inc., a nuclear and hazardous waste handling, processing, mitigation and management Company (in partnership and working jointly), in a combined response to offer recommendations and provide potential resolutions on the issues and problems identified in this subject report; present the following solution. A fully independent & Design Engineered, compact and portable, secure, self-enclosed, and skid mounted Processing and Storage Systems Facility. A system capable of being fully transportable for Nuclear Power Plant On-Site transfer of spent Ion Exchange Resins and Class B/C Driver Radioactive Isotopes into an induction heat melting, volume reduction MVS (modular vitrification system) processed, Low Level Radioactive Waste (LLRW) facility. This aforementioned "MVS-LLRW Processing Systems Facility" separately, individually, collectively, and concurrently

mitigates and resolves each and every one of the six (6) NRC Staff identified, potential, and environmental impacts. (As identified alternatives for managing low-level radioactive waste (LLRW) and spent ion exchange resins (IER's) being generated at commercial nuclear power plants (CNPP's), and as discussed in this subject report).

After reading this subject "NRC September 2012 Draft Comparative Report", the joint PENV-Kurion Commercial Nuclear Power Plant Projects Management and Engineering Team has decided to launch the development of their newly designed system. Readily accepting the engineering, design, and development challenges for a unique closed loop, independent, self-contained, and securely portable/transportable facility. A skid mounted, nuclear environment ready, low-level radioactive waste facility for the transfer, processing and storage of spent ion exchange resins and class B/C driver radioactive isotopes by MVS technology; reliant upon this NRC September 2012 Draft Comparative Report as the upper tier specification document for controlling the engineering, design, technical/operations input, specifications and requirements final document.

***NRC Response:*** *The NRC staff notes this comment and thanks the commenter for the information. No changes were made to the report as a result of this comment.*

### **B.3 References**

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(THOR<sup>sm</sup>, 2006) THOR Treatment Technologies, LLC. "THOR<sup>sm</sup> Steam Reforming Process for Hazardous and Radioactive Wastes, Technology Report, TR-SR02-1, Rev. 1." Richland, WA. ADAMS Accession No. ML120730124.

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