APPENDIX J
EVALUATION OF HUMAN HEALTH EFFECTS FROM TRANSPORTATION

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J.1 Introduction

Transportation of any commodity involves a risk to both transportation crew members and members of the public. This risk results directly from transportation-related accidents and indirectly from increased levels of pollution from vehicle emissions, regardless of the cargo. The transportation of certain materials, such as hazardous or radioactive waste, can pose an additional risk due to the unique nature of the material itself. To permit a complete appraisal of the environmental impacts of the Proposed Action and alternatives, the human health risks associated with the transportation of radioactive materials on public highways and railroads were assessed.

This appendix provides an overview of the approach used to assess the human health risks that could result from transportation. The topics in this appendix include the scope of the assessment, packaging and determination of potential transportation routes, analytical methods used for the risk assessment (e.g., computer models), and important assessment assumptions. In addition, to aid in the understanding and interpretation of the results, specific areas of uncertainty are described with an emphasis on how the uncertainties may affect comparisons of the alternatives.

The risk assessment results are presented in this appendix in terms of "per-shipment" risk factors, as well as the total risk for a given alternative. Per-shipment risk factors provide an estimate of the risk from a single shipment. The total risk for a given alternative is estimated by multiplying the expected number of shipments by the appropriate per-shipment risk factors.

J.2 Scope of Assessment

The scope of the transportation human health risk assessment, including the alternatives and options, transportation activities, potential radiological and nonradiological impacts, and transportation modes, is described in this section. There are several shipping arrangements for various radioactive wastes that cover all alternatives evaluated. This evaluation focuses on using public highways and rail systems. Additional details of the assessment are provided in the remaining sections of this appendix.

J.2.1 Transportation-related Activities

The transportation risk assessment is limited to estimating the human health risks related to transportation under each alternative. The risks to workers or to the public during loading, unloading, and handling prior to or after shipment are addressed in Section 4.1.9, Human Health and Safety, of this environmental impact statement (EIS). The impacts of increased transportation levels on local traffic flow and infrastructure are addressed in Section 4.1.2, Site Infrastructure.

J.2.2 Radiological Impacts

For each alternative, radiological risks (i.e., those risks that result from the radioactive nature of the materials) are assessed for both incident-free (i.e., normal) and accident transportation conditions. The radiological risk associated with incident-free transportation conditions would result from the potential exposure of people to external radiation in the vicinity of a shipment. The radiological risk from transportation accidents would come from the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of people.

All radiological impacts are calculated in terms of committed dose and associated health effects in the exposed populations. The radiation dose calculated is the total effective dose equivalent (see Title 10 of the *Code of Federal Regulations* [CFR], Part 20), which is the sum of the effective dose equivalent from external radiation exposure and the 50-year committed effective dose equivalent from internal radiation exposure. Radiation doses are presented in units of roentgen equivalent man (rem) for individuals and person-rem for collective populations. The impacts are further expressed as health risks in terms of latent cancer fatalities (LCFs) in exposed populations using the dose-to-risk conversion factors recommended by the U.S. Department of Energy (DOE) Office of National Environmental Policy Act (NEPA) Policy and Compliance, based on Interagency Steering Committee on Radiation Standards guidance (DOE 2003a).

J.2.3 Nonradiological Impacts

In addition to the radiological risks posed by transportation activities, vehicle-related risks are also assessed for nonradiological causes (i.e., causes related to the transport vehicles and not the radioactive cargo) for the same transportation routes. The nonradiological transportation risks, which would be incurred for similar shipments of any commodity, are assessed for accident conditions. The nonradiological accident risk refers to the potential occurrence of transportation accidents that result in fatalities unrelated to the radioactive nature of the cargo.

Nonradiological risks during incident-free transportation conditions could also be caused by potential exposure to increased vehicle exhaust emissions. As explained later in Section J.5.2, these emission impacts were not considered.

J.2.4 Transportation Modes

All shipments were assumed to take place by either dedicated truck or rail.

J.2.5 Receptors

Transportation-related risks are calculated and presented separately for workers and members of the general public. The workers considered are truck and rail crew members involved in transportation and inspection of the packages. The general public includes all persons who could be exposed to a shipment while it is moving or stopped during transit. For the incident-free operation, the affected population includes individuals living within 800 meters (0.5 miles) of each side of the road or rail line. Potential risks are estimated for the affected populations and for the hypothetical maximally exposed individual (MEI). For incident-free operation, the MEI would be a resident living near the highway or rail line and exposed to all shipments transported on the road or rail line. For accident conditions, the affected population includes individuals residing within 80 kilometers (50 miles) of the accident, and the MEI would be an individual located 100 meters (330 feet) directly downwind from the accident. The risk to the affected population is a measure of the radiological risk posed to society as a whole by the alternative being considered. As such, the impact on the affected population is used as the primary means of comparing various alternatives.

J.3 Packaging and Transportation Regulations

This section provides a high-level, brief summary of packaging and transportation regulations. The regulations pertaining to the transportation of radioactive materials from the Western New York Nuclear Service Center (WNYNSC) are detailed in the CFR published by the U.S. Department of Transportation (DOT) and U.S. Nuclear Regulatory Commission (NRC). Specifics on details on these regulations can be found in

49 CFR Parts 106, 107, and 171-178 (DOT regulations); 10 CFR Parts 20, 61, and 71 (NRC regulations); and 39 CFR Part 121 (U.S. Postal Service regulations). Interested readers are encouraged to visit the cited sections of the CFR for current detailed regulations, or review the DOT RAMREG-001-98 (DOT 1998) for a comprehensive discussion on radioactive material regulations.

J.3.1 Packaging Regulations

The primary regulatory approach to promote safety from radiological exposure is the specification of standards for the packaging of radioactive materials. Packaging represents the primary barrier between the radioactive material being transported and the public, workers, and the environment. Transportation packaging for radioactive materials must be designed, constructed, and maintained to contain and shield its contents during normal transport conditions. For highly radioactive material, such as high-level radioactive waste or spent nuclear fuel, packaging must contain and shield the contents in the event of severe accident conditions. The type of packaging used is determined by the total radioactive hazard presented by the material within the packaging. Four basic types of packaging are used: Excepted, Industrial, Type A, and Type B. Specific requirements for these packages are detailed in 49 CFR Part 173, Subpart I. All packages are designed to protect and retain their content under normal operations.

Excepted packagings are limited to transporting materials with extremely low levels of radioactivity and very low external radiation. Industrial packagings are used to transport materials that, because of their low concentration of radioactive materials, present a limited hazard to the public and the environment. Type A packagings are designed to protect and retain their contents under normal transport conditions, and because of higher radioactive content it must maintain sufficient shielding to limit radiation exposure to handling personnel. Type A packaging, typically a 0.21-cubic-meter (55-gallon) drum or standard waste box, is commonly used to transport radioactive materials with higher concentrations or amounts of radioactivity than Excepted or Industrial packages. Type B packagings are used to transport material with the highest radioactivity levels, and are designed to protect and retain their contents under transportation accident conditions. They are described in more detail in the following sections. Packaging requirements are an important consideration for transportation risk assessment.

Radioactive materials shipped in Type A containers, or packagings, are subject to specific radioactivity limits, identified as A1 and A2 values in 49 CFR 173.435, “Table of A1 and A2 Values for Radionuclides.” In addition, external radiation limits, as prescribed in 49 CFR 173.441, “Radiation Level Limitations”, must be met. If the A1 or A2 limits are exceeded, the material must be shipped in a Type B container unless it can be demonstrated that the material meets the definition of “low specific activity.” If the material qualifies as low-specific-activity as defined in 10 CFR Part 71, “Packaging and Transportation of Radioactive Material”, and 49 CFR Part 173, it may be shipped in a shipping container such as Industrial or Type A Packaging (49 CFR 173.427); see also RAMREG-001-98 (DOT 1998). Type B containers, or casks, are subject to the radiation limits in 49 CFR 173.441, but no quantity limits are imposed except in the case of fissile materials and plutonium.

Type A packagings are designed to retain their radioactive contents in normal transport. Under normal conditions, a Type A package must withstand:

- Operating temperatures ranging from -40 degrees Celsius (°C) (-40 degrees Fahrenheit [°F]) to 70 °C (158 °F);
- External pressures ranging from 0.25 to 1.4 kilograms per square centimeter (3.5 to 20 pounds per square inch);
- Normal vibration experienced during transportation;

- Simulated rainfall of 5 centimeters (2 inches) per hour for 1 hour;
- Free fall from 0.3 to 1.2 meters (1 to 4 feet), depending on the package weight;
- Water immersion-compression tests; and
- Impact of a 6-kilogram (13-pound) steel cylinder with rounded ends dropped from 1 meter (3.3 feet) onto the most vulnerable surface.

Type B packagings are designed to retain their radioactive contents in both normal and accident conditions. In addition to the normal conditions outlined earlier, under accident conditions, a Type B package must withstand:

- Free drop from 9 meters (30 feet) onto an unyielding surface in a position most likely to cause damage;
- Free drop from 1 meter (3.3 feet) onto the end of a 15-centimeter (6-inch) diameter vertical steel bar;
- Exposure to temperatures of 800 °C (1,475 °F) for at least 30 minutes;
- For all packages, immersion in at least 15 meters (50 feet) of water;
- For some packages, immersion in at least 0.9 meters (3 feet) of water in an orientation most likely to result in leakage; and
- For some packages, immersion in at least 200 meters (660 feet) of water for 1 hour.

Compliance with these requirements is demonstrated by using a combination of simple calculation methods, computer modeling techniques, or scale-model or full-scale testing of transportation packages or casks.

J.3.2 Transportation Regulations

The regulatory standards for packaging and transporting radioactive materials are designed to achieve four primary objectives:

- Protect persons and property from radiation emitted from packages during transportation by specific limitations on the allowable radiation levels;
- Contain radioactive material in the package (achieved by packaging design requirements based on performance-oriented packaging integrity tests and environmental criteria);
- Prevent nuclear criticality (an unplanned nuclear chain reaction that could occur as a result of concentrating too much fissile material in one place); and
- Provide physical protection against theft and sabotage during transit.

DOT regulates the transportation of hazardous materials in interstate commerce by land, air, and water. DOT specifically regulates the carriers of radioactive materials and the conditions of transport, such as routing, handling and storage, and vehicle and driver requirements. DOT also regulates the labeling, classification, and marking of radioactive material packagings.

The NRC regulates the packaging and transporting of radioactive material for its licensees, including commercial shippers of radioactive materials. In addition, under an agreement with DOT, the NRC sets the standards for packages containing fissile materials and Type B packagings.

DOE, through its management directives, Orders, and contractual agreements, ensures the protection of public health and safety by imposing on its transportation activities standards equivalent to those of DOT and the NRC. According to 49 CFR 173.7(d), packagings made by or under the direction of DOE may be used for transporting Class 7 materials (radioactive materials) when the packages are evaluated, approved, and certified by DOE against packaging standards equivalent to those specified in 10 CFR Part 71.

DOT also has requirements that help reduce transportation impacts. Some requirements affect drivers, packaging, labeling, marking, and placarding. Others specifying the maximum dose rate from radioactive material shipments help reduce incident-free transportation doses.

The Department of Homeland Security (DHS) is responsible for establishing policies for, and coordinating civil emergency management, planning, and interaction with, Federal Executive agencies that have emergency response functions in the event of a transportation incident. Guidelines for response actions have been outlined in the *National Response Framework (NRF)* (DHS 2008a) in the event a transportation incident involving nuclear material occurs.

DHS would use the Federal Emergency Management Agency, an organization within DHS, to coordinate Federal and state participation in developing emergency response plans and to be responsible for the development and maintenance of the *Nuclear/Radiological Incident Annex (NRIA)* to the *NRF* (DHS 2008b). *NRIA/NRF* describes the policies, situations, concepts of operations, and responsibilities of the Federal departments and agencies governing the immediate response and short-term recovery activities for incidents involving release of radioactive materials to address the consequences of the event.

J.4 Transportation Analysis Impact Methodology

The transportation risk assessment is based on the alternatives described in Chapter 2 of this EIS. **Figure J–1** summarizes the transportation risk assessment methodology. After the EIS alternatives were identified and the requirements of the shipping campaign were understood, data were collected on material characteristics and accident parameters.

Transportation impacts calculated in this EIS are presented in two parts: impacts of incident-free or routine transportation and impacts of transportation accidents. Impacts of incident-free transportation and transportation accidents were further divided into nonradiological and radiological impacts. Nonradiological impacts could result from transportation accidents in terms of traffic fatalities. Radiological impacts of incident-free transportation include impacts on members of the public and crew from radiation emanating from materials in the shipment. Radiological impacts from accident conditions consider all foreseeable scenarios that could damage transportation packages leading to releases of radioactive materials to the environment.

The impact of transportation accidents is expressed in terms of probabilistic risk, which is the probability of an accident multiplied by the consequences of that accident and summed over all reasonably conceivable accident conditions. Hypothetical transportation accident conditions ranging from low-speed "fender-bender" collisions to high-speed collisions with or without fires were analyzed. The frequencies of accidents and consequences were evaluated using a method developed by the NRC and previously published in the *Final Environmental Impact Statement on the Transportation of Radioactive Materials by Air and Other Modes*, NUREG-0170 (NRC 1977); *Shipping Container Response to Severe Highway and Railway Accident Conditions*, NUREG/CR-4829 (NRC 1987); and *Reexamination of Spent Fuel Shipping Risk Estimates*, NUREG/CR-6672 (NRC 2000). Hereafter, these reports are cited as: *Radioactive Material Transport Study*, NUREG-0170; *Modal Study*, NUREG/CR-4829; and *Reexamination Study*, NUREG/CR-6672. Radiological accident risk is expressed in terms of additional LCFs, and nonradiological accident risk is expressed in terms of additional immediate (traffic) fatalities. Incident-free risk is also expressed in terms of additional LCFs.

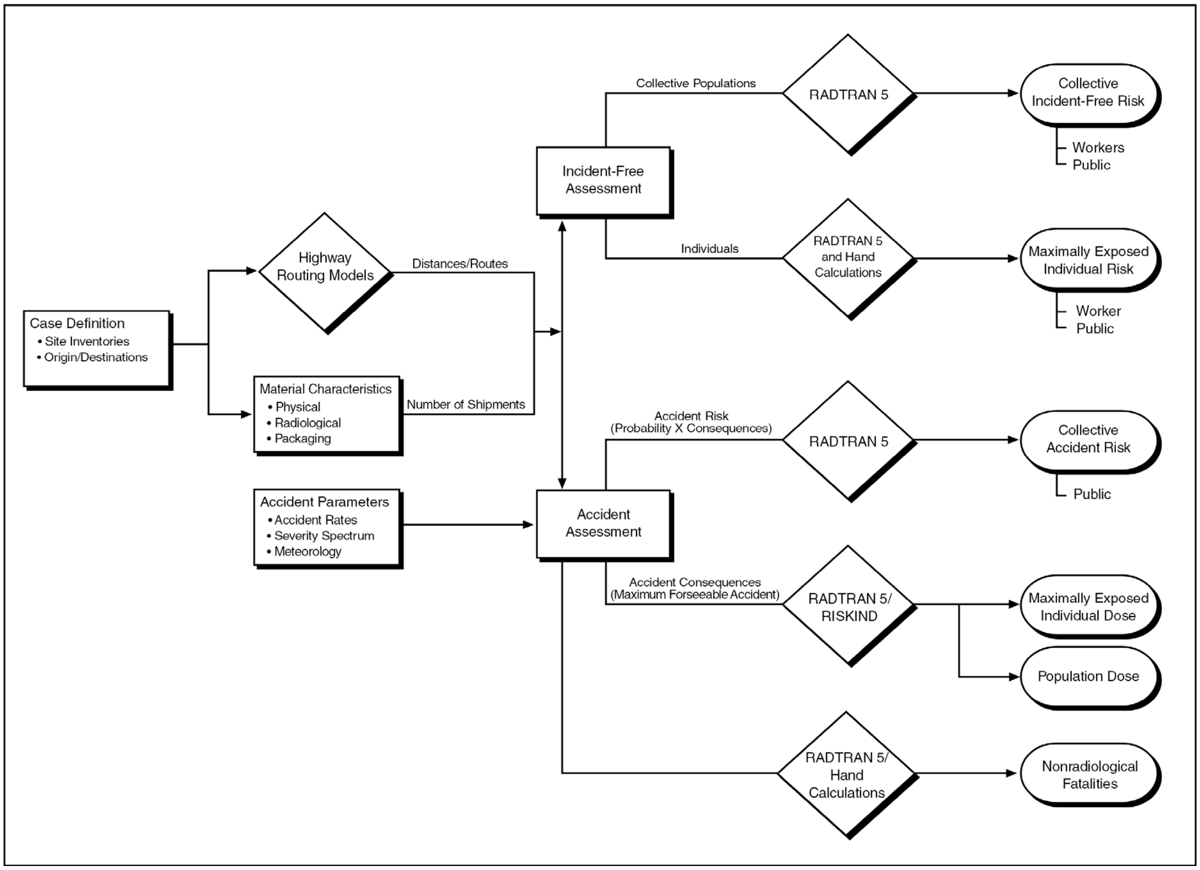

Figure J–1 Transportation Risk Assessment

Transportation-related risks were calculated and are presented separately for workers and members of the general public. The workers considered are truck/rail crew members involved in the actual transportation. The general public includes all persons who could be exposed to a shipment while it is moving or stopped during transit.

The first step in the ground transportation analysis was to determine the distances and populations along the routes. The Transportation Routing Analysis Geographic Information System (TRAGIS) computer program (Johnson and Michelhaugh 2003) was used to choose representative routes and the associated distances and populations. This information, along with the properties of the material being shipped and route-specific accident frequencies, was entered into the RADTRAN 5 computer code (Neuhauser and Kanipe 2003), which calculates incident and accident risks on a per-shipment basis. The risks under each alternative were determined by summing the products of per-shipment risks for each waste type by its number of shipments.

The RADTRAN 5 computer code (Neuhauser and Kanipe 2003) was used for incident-free and accident risk assessments to estimate the impacts on populations. RADTRAN 5 was developed by Sandia National Laboratories to calculate population risks associated with the transportation of radioactive materials by a variety of modes, including truck, rail, air, ship, and barge. RADTRAN 5 was used to calculate the doses to MEIs during incident-free operations.

The RADTRAN 5 population risk calculations include both the consequences and probabilities of potential exposure events. The RADTRAN 5 code consequence analyses include the following exposure pathways: cloud shine, ground shine, direct radiation (from loss of shielding), inhalation (from dispersed materials), and resuspension (inhalation dose from resuspended materials) (Neuhauser et al. 2000). The collective population risk is a measure of the total radiological risk posed to society as a whole by the alternative being considered. As such, the collective population risk is used as the primary means of comparing the various alternatives.

The RISKIND computer code (Yuan et al. 1995) was used to estimate the doses to MEIs and populations for the worst-case maximum reasonably foreseeable transportation accident. The RISKIND computer code was developed for DOE's Office of Civilian Radioactive Waste Management to analyze the exposure of individuals during incident-free transportation. In addition, the RISKIND code was designed to allow a detailed assessment of the consequences to individuals and population subgroups from severe transportation accidents under various environmental settings.

The RISKIND calculations were conducted to supplement the collective risk results calculated with RADTRAN 5. Whereas the collective risk results provide a measure of the overall risks of each alternative, the RISKIND calculations are meant to address areas of specific concern to individuals and population subgroups. Essentially, the RISKIND analyses are meant to address "What if" questions, such as "What if I live next to a site access road?" or "What if an accident happens near my town?"

J.4.1 Transportation Routes

To assess incident-free and transportation accident impacts, route characteristics were determined for offsite shipments from WNYNSC. Some of the wastes that would be generated do not currently have available disposal options. For these wastes, existing disposal sites in the eastern and western United States were used as proxy locations to define route characteristics for purposes of analysis. Route characteristics between WNYNSC and the following locations were analyzed:

- the Hanford Site in Richland, Washington (western proxy site for commercial Class B and C waste disposal);
- the Nevada Test Site (NTS) in Mercury, Nevada (DOE low-level radioactive waste; western proxy site for Greater-Than-Class C waste disposal);[1]
- the EnergySolutions site in Clive, Utah;
- the Barnwell site in Barnwell, South Carolina[2] (eastern proxy site for commercial Class B and C waste disposal); and
- the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico (proxy site for transuranic waste disposal).[3]

For offsite transport, highway and rail routes were determined using TRAGIS (Johnson and Michelhaugh 2003).[4]

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[1] *A disposal facility for Greater-Than-Class C low-level radioactive waste and potential non-defense transuranic waste will be evaluated in the Disposal of Greater-Than-Class C Low-Level Radioactive Waste Environmental Impact Statement (DOE/EIS-0375).*

[2] *Since July 2008, Barnwell does not accept waste from sites outside the Southeast Compact.*

[3] *See note 1.*

[4] *There is direct rail access to the Hanford Site, Barnwell, and EnergySolutions. Direct rail access to NTS is not available at the present time. However, for purposes of comparison between alternatives, a rail line with routing characteristics consistent with those used in the Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada is being used. For WIPP, while there is currently rail infrastructure at WIPP, there are no current plans to upgrade it so that rail shipments can be received.*

The TRAGIS computer program is a geographic information system-based transportation analysis computer program used to identify and select highway, rail, and waterway routes for transporting radioactive materials within the United States. Both the road and rail network are 1:100,000-scale databases, which were developed from the U.S. Geological Survey digital line graphs and the U.S. Bureau of the Census Topological Integrated Geographic Encoding and Referencing System. The population densities along each route were derived from 2000 census data (Johnson and Michelhaugh 2003). The features in TRAGIS allow users to determine routes for shipment of radioactive materials that conform to DOT regulations as specified in 49 CFR Part 397.

Offsite Route Characteristics

Route characteristics that are important to the radiological risk assessment include the total shipment distance and population distribution along the route. The specific route selected determines both the total potentially exposed population and the expected frequency of transportation-related accidents. Route characteristics for Hanford, NTS, EnergySolutions, Barnwell, and WIPP transportation are summarized in **Table J–1**. Rural, suburban, and urban areas are characterized according to the following breakdown:

- Rural population densities range from 0 to 54 persons per square kilometer (0 to 139 persons per square mile);
- Suburban population densities range from 55 to 1,284 persons per square kilometer (140 to 3,326 persons per square mile); and
- Urban population densities include all population densities greater than 1,284 persons per square kilometer (3,326 persons per square mile).

Table J–1 Offsite Transport Truck and Rail Route Characteristics

Origin	Destination	Nominal Distance (kilometers)	Distance Traveled in Zones (kilometers)			Population Density in Zone (number per square kilometer)			Number of Affected Persons [a]
			Rural	Suburban	Urban	Rural	Suburban	Urban	
Truck Routes									
WNYNSC	Hanford [b]	4,112	3,242	789	82	11.2	293.3	2,309.4	729,874
	NTS	3,922	3,058	753	112	11.0	307.5	2,428.4	857,664
	EnergySolutions	3,245	2,508	657	81	11.6	301.7	2,352.8	669,173
	Barnwell [b]	1,507	885	587	35	17.4	310	2,198.5	439,565
	WIPP	3,154	2,104	947	104	14.5	319.2	2,254	906,393
Rail Routes									
WNYNSC	Hanford	4,195	3,348	680	167	7.3	388.7	2,420	1,106,817
	NTS [c]	4,330	3,533	629	167	7.4	387.2	2,433.1	1,083,071
	EnergySolutions	3,425	2,636	622	167	9.6	387.5	2,434	1,077,838
	Barnwell [b]	1,784	1,170	519	95	15.7	385.6	2,404.2	715,606
	WIPP	2,962	2,344	486	132	8.7	438.3	2,391.9	878,996

NTS = Nevada Test Site, WIPP = Waste Isolation Pilot Plant, WNYNSC = Western New York Nuclear Service Center.

[a] The estimated number of persons residing within 800 meters (0.5 miles) along the transportation route.

[b] WNYNSC–Hanford Site route characteristics were used as a proxy for a commercial western U.S. disposal site for Class B/C wastes. Barnwell Site disposal of this waste was also evaluated in this appendix as a proxy for an eastern U.S. disposal site for Class B/C wastes, to provide environmental impact coverage and flexibility for use, should a site become available in future.

[c] For the purpose of analysis, NTS rail route characteristics were assumed to be the same as those used in the *Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*.

Note: To convert from kilometers to miles, multiply by 0.6214; to convert from number per square kilometer to number per square mile, multiply by 2.59.

The affected population for route characterization and incident-free dose calculation includes all persons living within 800 meters (0.5 miles) of each side of the transportation route.

Analyzed truck and rail routes for shipments of radioactive waste materials to the Hanford, NTS, Barnwell, EnergySolutions, and WIPP sites are shown on **Figure J–2**.

J.4.2 Radioactive Material Shipments

Transportation of all waste types was assumed to be in certified or certified-equivalent packaging on exclusive-use vehicles. Legal-weight heavy-haul combination trucks are used for highway transportation. Type A packages are transported on common flatbed or covered trailers; Type B packages are generally shipped on trailers designed specifically for the packaging being used. For transportation by truck, the maximum payload weight is considered to be about 22,000 kilograms (about 48,000 pounds), based on the Federal gross vehicle weight limit of 36,288 kilograms (80,000 pounds). While there are large numbers of multi-trailer combinations (known as longer combination vehicles) with gross weights in excess of the Federal limit in operation on rural roads and turnpikes in some states (FHWA 2003), for evaluation purposes, the load limit for the legal truck was based on the Federal gross vehicle weight.

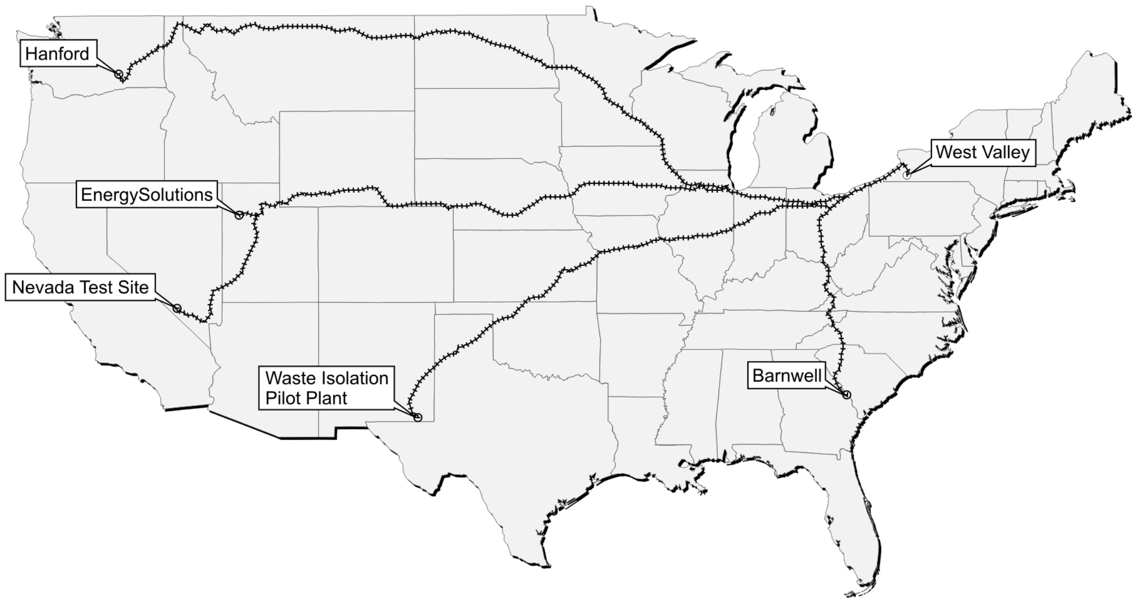
Rail transport can be done with dedicated and/or general freight trains. For analysis purposes, a dedicated train was assumed. The payload weights for railcars range from 45,359 to 68,039 kilograms (100,000 to 150,000 pounds). A median payload weight of 54,431 kilograms (120,000 pounds) was used in this analysis.

Several types of containers would be used to transport the generated waste. The various wastes that would be transported under the alternatives in this EIS include demolition and construction debris and hazardous waste, low-level radioactive waste, transuranic waste, and mixed low-level radioactive waste. **Table J–2** lists the types of containers used, along with their volumes and the number of containers in a shipment. A shipment is defined as the amount of waste transported on a single truck or a single railcar. Multiple railcars (two or more railcars carrying waste) per train could be used to reduce the number of rail transport. As the rail accident and fatalities data are per railcar-kilometer (see section J.6.2), the transportation analysis presented here is based on one railcar (carrying waste) per transport. While it may be possible to reduce the number of transports by using multiple railcars per train, there would be a proportional increase in the transportation risks per transport.

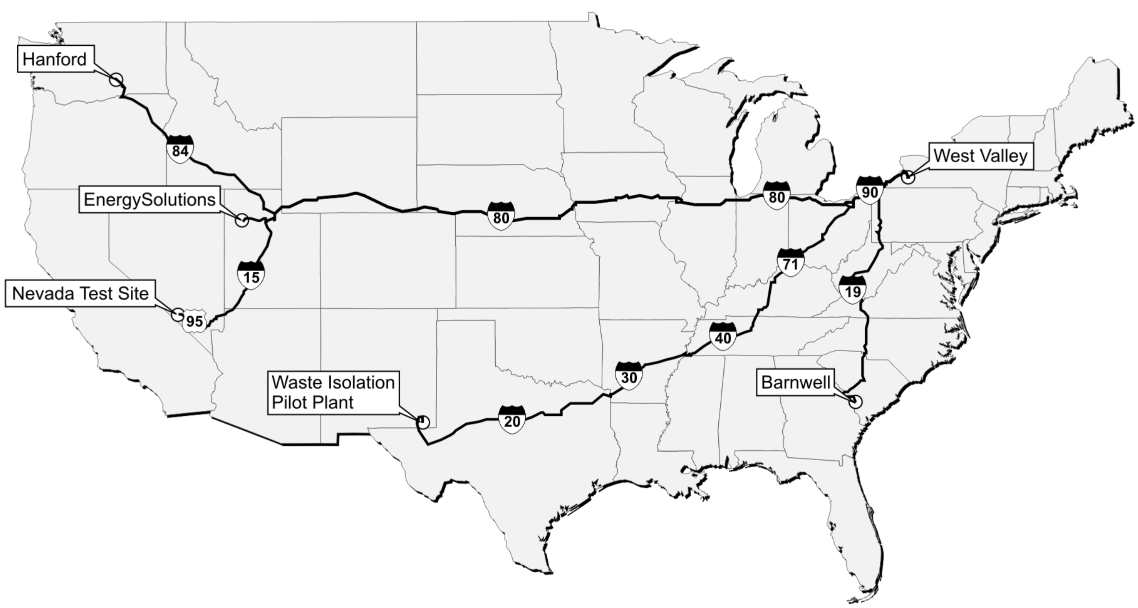
The number of shipping containers per shipment was estimated on the basis of dimensions and weight of the shipping containers, the Transport Index,[5] and the transport vehicle dimensions and weight limits. In general, the various wastes were assumed to be transported on standard truck semi-trailers and railcars in a single stack.

Waste materials to be transported offsite for disposal were classified in three broad disposal groupings: construction and demolition debris, hazardous wastes, and radioactive wastes. Trash, such as waste paper generated from routine office work, is not included. Radioactive wastes were classified in accordance with NRC regulations in 10 CFR Part 61. For DOE radioactive waste to be transported to a DOE radioactive waste disposal site (e.g., NTS) it was assumed that the wastes would meet the disposal facility's waste acceptance criteria. Wastes exceeding Class C limits that were buried in the NRC-Licensed Disposal Area (NDA) and State-Licensed Disposal Area (SDA) prior to establishment of the West Valley Demonstration Project (WVDP) were assumed to be Greater-Than-Class C wastes. This waste includes the irradiated, unprocessed reactor fuels that were mixed with concrete in drums and disposed of at NDA. All other wastes exceeding Class C limits were assumed to be transuranic wastes.

[5] *Transport Index is a dimensionless number (rounded up to the next tenth) placed on label of a package, to designate the degree of control to be exercised by the carrier. Its value is equivalent to the maximum radiation level in millirem per hour at 1 meter (3.3 feet) from the package (10 CFR 71.4 and 49 CFR 173.403).*



Analyzed Rail Routes



Analyzed Truck Routes

Figure J–2 Analyzed Truck and Rail Routes

Table J–2 Waste Type and Container Characteristics

Waste Type	*Container*	*Container Volume (cubic meters)* [a]	*Container Mass (kilograms)* [b]	*Number of Containers per Shipment*
Class A low-level radioactive waste	208-liter drum	0.21	399	80 per truck 160 per rail
Class A low-level radioactive waste and mixed low-level radioactive waste	B-25 Box	2.55	4,536	5 per truck 10 per rail
Class B and Class C low-level radioactive waste	B-25 Box	2.55	4,536	5 per truck 10 per rail
Class B and Class C low-level radioactive waste	High-integrity container [c]	5.10	9,072	1 per truck 2 per rail
Class C (remote-handled) [d]	208-liter drum	0.21	399	10 per truck cask 2 casks per rail
Greater-Than-Class C waste [d]	208-liter drum	0.21	399	10 per truck cask 2 casks per rail
Low-specific-activity waste	Lift liner	7.31	10,886	2 per truck 4 per rail
Transuranic waste (remote-handled) [e]	208-liter drum	0.21	399	3 per truck cask 2 casks per rail
Transuranic waste (contact-handled)	208-liter drum	0.21	399	14 per TRUPACT II; 3 TRUPACT IIs per truck 6 TRUPACT IIs per rail
Construction/demolition debris	Roll-on/Roll-off	15.30	Not applicable	1 per truck
Hazardous	208-liter drum	0.21	399	40 per truck

NRC = U.S. Nuclear Regulatory Commission, TRUPACT II = transuranic waste package transporter II.
[a] Container exterior volume. To convert from cubic meters to cubic feet, multiply by 35.315; from liters to gallons, by 0.26417.
[b] Filled container maximum mass. Container mass includes the mass of the container shell, its internal packaging, and the materials within. To convert from kilograms to pounds, multiply by 2.2046.
[c] High-integrity containers (NUHIC-205) would be transported in a shielded cask, if needed to limit the external dose rate.
[d] Remote-handled Class C and Greater-Than-Class C waste drums are transported in Type B shipping casks. The Greater-Than-Class C waste includes fuel and hardware wastes buried in the NRC-Licensed Disposal Area. Class B wastes packaged in drums, were assumed to be transported using shielded cask.
[e] Remote-handled transuranic waste drums must be transported in a Type B cask.
Note: Construction debris and hazardous wastes would be shipped to a local offsite location by truck only.
Source: WSMS 2009e.

For the purposes of analysis, this EIS assumes that all DOE low-level radioactive waste can be disposed of at NTS or EnergySolutions in Clive, Utah, depending on waste classification. It also assumes that low-level radioactive waste from the SDA, and pre-1982 NDA waste, would be disposed of at a commercial disposal site.

The commercial sites considered include EnergySolutions for low-specific-activity and Class A waste, and the eastern and western proxy sites of Barnwell and Hanford, respectively, for Class B and C waste.

It is also expected that Greater-Than-Class C waste would be generated during the exhumation and closure of the SDA and the pre-WVDP burial areas in the NDA. There is no known disposal facility for this waste at the present time. A disposal facility for Greater-Than-Class C low-level radioactive waste and potential non-defense transuranic waste will be determined in the Record of Decision for the *Disposal of Greater-Than-Class C Low-Level Radioactive Waste Environmental Impact Statement (GTCC EIS)* (DOE/EIS-0375). However, for the purposes of analyses in this EIS, it was assumed that Greater-Than-Class C waste would be disposed of at NTS. In addition to NTS, several other DOE sites and generic commercial locations for the disposal of Greater-Than-Class C waste will be evaluated in the *GTCC EIS*.

Transuranic and Class A mixed low-level radioactive waste would also be generated during closure activities. Class A mixed low-level radioactive waste was assumed to be disposed of at EnergySolutions under all disposal options. The only disposal location currently approved for transuranic waste is WIPP. WIPP is currently authorized to accept only DOE defense waste, and the *Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement (WIPP SEIS)* (DOE 1997) evaluated disposal of WVDP transuranic waste. However, WVDP non-defense transuranic waste cannot be disposed of at WIPP. As previously stated, a disposal facility for Greater-Than-Class C low-level radioactive waste and potential non-defense transuranic waste will be determined in the Record of Decision for the *GTCC EIS* (DOE/EIS-0375). Nevertheless, for the purposes of analysis only, in this EIS, the generated transuranic waste was assumed to be disposed of at WIPP.

J.4.3 Radionuclide Inventories

The details on the volumes and types of generated wastes and potential radioactive inventories at each of the waste management areas (WMAs) are provided in the technical reports and their supporting documents for each of the alternatives (WSMS 2009a, 2009b, 2009c, 2009d), and are summarized in Appendix C of this EIS. As indicated in Appendix C and the related referenced documents, the activities under each alternative would include closure (excavation) or remediation of 12 WMAs, the Cesium Prong, and North Plateau Groundwater Plume; decontamination, demolition, and decommissioning of buildings and underground structures; and construction, operation, and demolition of additional support facilities. These activities would result in multiple waste volumes of similar waste class with different radioactive inventories. Among the WMAs, the three largest radionuclide inventories are in the buried waste or equipment in the NDA, SDA, and Waste Tank Farm. Therefore, for the purposes of evaluating transportation accidents, the radionuclide inventories in various waste classes were estimated from radionuclide inventories in these three areas (URS 2000, 2002; WVNS 2005). The radionuclide inventory estimates at these areas were converted to radionuclide concentrations in each waste class based on the estimated disposed waste volumes in the NDA and SDA area, and the expected waste volumes in the Waste Tank Farm. The use of disposed waste volumes would lead to a higher calculated radionuclide concentration than would be expected using that of retrieved waste volumes. The waste retrieval process would lead to a higher waste volume due to cross contamination of the soil around the disposed waste. For similar waste classes with different radionuclide concentrations, the maximum radionuclide concentrations were selected to lead to the greatest radiological hazards for transportation risk assessment. The selected radionuclide concentrations were assumed to represent the concentrations for all similar waste classes that could be generated in other WMAs. This method was deemed necessary to eliminate producing multiple radionuclide concentrations for the same waste class and to produce an enveloping set of transportation accident risks.

Tables J–3 and **J–4** provide the container radionuclide inventories for each waste class. The list of radionuclides in these tables is limited to those that, in sum, contribute more than 99 percent of the total dose in an accident. Given the list, the corresponding concentration is derived from waste inventory. Note that the values given represent the maximum concentration that could be present in a container. If the actual waste container inventory were to exceed the A_2 limit (10 CFR Part 71; 49 CFR 173.435), the waste class would be shipped in a Type B cask. As Class B and Class C wastes could be shipped to a disposal site on the same type of transporter, a conservative inventory applicable to both waste class types was selected and provided in Table J–3. In the absence of a precise waste characterization for the low-specific-activity waste, the inventory for low-specific-activity waste was assumed to correspond to a low-specific-activity waste with the maximum concentration that was disposed of at the SDA.

Table J–3 Low-Specific-Activity, Class A, B, C and Greater-Than-Class C Waste Container Inventories (curies)

Radionuclides	Low Specific Activity	Class A LLW		Class B and Class C LLW		GTCC Waste
	Lift liner [a]	Drum	Box [b]	Box	HIC	Drum
Tritium	2.84×10^{-2}	1.14×10^{-2}	1.24×10^{-1}	3.72×10^{1}	7.35×10^{1}	2.00
Carbon-14	1.63×10^{-3}	8.44×10^{-5}	9.18×10^{-4}	2.76×10^{-1}	5.45×10^{-1}	1.48×10^{-2}
Iron-55	–	5.12×10^{-5}	5.57×10^{-4}	1.67×10^{-1}	3.30×10^{-1}	8.98×10^{-3}
Cobalt-60	3.10×10^{-3}	1.47×10^{-3}	1.60×10^{-2}	4.80	9.49	2.58×10^{-1}
Nickel-63	–	5.69×10^{-3}	6.20×10^{-2}	1.86×10^{1}	3.67×10^{1}	9.99×10^{-1}
Strontium-90	9.20×10^{-4}	4.12×10^{-4}	4.49×10^{-3}	2.04×10^{-1}	4.03×10^{-1}	1.85
Yttrium-90	9.20×10^{-4}	4.12×10^{-4}	4.49×10^{-3}	2.04×10^{-1}	4.03×10^{-1}	1.85
Cesium-137	1.52×10^{-3}	4.03×10^{-3}	4.39×10^{-2}	1.32×10^{1}	2.60×10^{1}	2.35
Barium-137m	1.44×10^{-3}	3.81×10^{-3}	4.15×10^{-2}	1.25×10^{1}	2.46×10^{1}	2.23
Thorium-234	–	5.29×10^{-5}	5.76×10^{-4}	1.73×10^{-1}	3.41×10^{-1}	2.68×10^{-2}
Uranium-238	–	5.29×10^{-5}	5.76×10^{-4}	1.73×10^{-1}	3.41×10^{-1}	9.28×10^{-3}
Plutonium-238 [c]	1.10×10^{-6}	3.09×10^{-5}	3.37×10^{-4}	1.01×10^{-1}	2.00×10^{-1}	2.67
Plutonium-239 [c]	1.10×10^{-6}	5.08×10^{-5}	5.53×10^{-4}	1.66×10^{-1}	3.28×10^{-1}	3.63×10^{-2}
Plutonium-240 [c]	1.10×10^{-6}	3.02×10^{-5}	3.28×10^{-4}	9.85×10^{-2}	1.95×10^{-1}	1.88×10^{-1}
Plutonium-241 [c]	1.10×10^{-6}	1.07×10^{-3}	1.17×10^{-2}	3.50	6.91	1.05
Americium-241	1.10×10^{-6}	1.21×10^{-4}	1.32×10^{-3}	3.95×10^{-1}	7.80×10^{-1}	1.16×10^{-1}

GTCC = Greater-Than-Class C, HIC = high integrity container, LLW = low-level radioactive waste.
[a] The values are curies per cubic meter.
[b] Also used for mixed low-level radioactive waste.
[c] These radionuclides were added to the low-specific-activity waste using similar concentration as that for Americium-241.

Table J–4 Fuel and Hardware, Remote-Handled Class C and Transuranic Container Inventories (curies)

Radionuclides	Fuel/ Hardware	Class C-R	TRU	Radionuclides	Fuel/ Hardware	Class C-R	TRU
Tritium	3.11	–	–	Neptunium-237	7.94×10^{-3}	2.79×10^{-5}	6.64×10^{-4}
Carbon-14	4.75×10^{-1}	1.42×10^{-6}	1.60×10^{-6}	Uranium-238	1.31×10^{-1}	2.85×10^{-5}	8.93×10^{-6}
Cobalt-60	2.73×10^{1}	–	–	Plutonium-238	1.05×10^{1}	4.01×10^{-3}	1.83×10^{-1}
Strontium-90	1.33×10^{3}	2.16	4.93×10^{1}	Plutonium-239	4.12×10^{1}	7.59×10^{-4}	4.58×10^{-2}
Yttrium-90	1.33×10^{3}	2.16	4.93×10^{1}	Plutonium-240	2.21×10^{1}	5.46×10^{-4}	3.32×10^{-2}
Cesium-137	1.73×10^{3}	6.40×10^{2}	8.82×10^{1}	Plutonium-241	6.71×10^{2}	4.51×10^{-2}	9.85×10^{-1}
Barium-137m	1.64×10^{3}	6.05×10^{2}	8.34×10^{1}	Americium-241	7.99×10^{1}	1.15×10^{-2}	4.81×10^{-1}
				Curium-244	6.26×10^{-1}	2.02×10^{-3}	9.97×10^{-2}

Class C-R = Class C remote-handled waste, TRU = transuranic.
The inventories refer to the amount of curies in a 208-liter (55-gallon) drum.

J.5 Incident-free Transportation Risks

J.5.1 Radiological Risk

During incident-free transportation of radioactive materials, radiological dose results from exposure to the external radiation field that surrounds the shipping containers. The population dose is a function of the number of people exposed, their proximity to the containers, the length of time of exposure, and the intensity of the radiation field surrounding the containers.

Radiological impacts were determined for crew members and the general population during incident-free transportation. For truck shipments, the crew members are the drivers of the shipment vehicle. For rail shipments, the crew consists of workers in close proximity to the shipping containers during inspection or classification of railcars. The general population is composed of persons residing within 800 meters (0.50 miles) of the truck or rail routes (off-link), persons sharing the road or railway (on-link), and persons at stops. Exposures to workers who would load and unload the shipments are not included in this analysis, but are included in the occupational estimates for plant workers. Exposures to the inspectors and escorts are evaluated and presented separately.

Collective doses for the crew and general population were calculated by using the RADTRAN 5 computer code (Neuhauser and Kanipe 2003). The radioactive material shipments were assigned an external dose rate based on their radiological characteristics. Offsite transportation of the radioactive material has a defined regulatory limit of 10 millirem per hour at 2 meters (about 6.6 feet) from the cask (10 CFR 71.47; 49 CFR 173.441). If a waste container shows a high external dose rate that could exceed the DOT limit of 10 millirem per hour at 2 meters (6.6 feet) from the outer, or lateral, edge of the vehicle, it would be transported in a Type A or Type B shielded shipping container. Waste container dose rate, or its Transport Index, is dependent on distribution and quantities of radionuclides, waste density, shielding provided by the packaging, and self-shielding provided by the waste mixture. The most important gamma-emitting radionuclides in the waste are cobalt-60 and cesium-137. The MicroShield computer program (Grove 2003) was used to estimate the external dose rates for the various waste containers based on the unit concentrations of cobalt-60 and cesium-137. Dose rate calculations were performed assuming both shielded and bare containers. For the shielded option, waste containers were assumed to be in appropriate Type A or Type B shipping containers. For example, Greater-Than-Class C and remote-handled transuranic wastes were assumed to be shipped in a CNS 10-160B or a RH-72B cask (both are Type B casks), and Class C remote-handled waste in a CNS 10-160B cask. Using an enveloping waste composition (i.e., wastes with the highest potential cobalt-60 and/or cesium-137 concentrations) for each waste type, a conservative dose rate for its container was calculated. These dose rates were compared with those used in other DOE NEPA documentation, and an appropriate conservative value was assigned to each waste type. Dose rates for Class A low-level radioactive waste and mixed low-level radioactive waste were assigned at 2 millirem per hour at 1 meter (about 3.3 feet). Dose rate for low-specific-activity waste was assigned at 0.10 millirem per hour at 1 meter. Dose rates for the remote-handled Class C and Greater-Than-Class C wastes in Type B casks were assigned at 16 millirem per hour at 1 meter. Dose rates for the contact-handled Class B and Class C wastes in unshielded B-25 boxes or high integrity containers were also assigned at 16 millirem per hour at 1 meter. The dose rate for the remote-handled transuranic waste in a CNS 10-160B package at 1 meter was assigned at 5 millirem per hour. The dose rate for the contact-handled transuranic[6] waste was assigned at 4 millirem per hour at 1 meter (DOE 1997). In all cases, the maximum external dose rate is less than, or equal to the regulatory limit of 10 millirem per hour at 2 meters from each container.

To calculate the collective dose, a unit risk factor was developed to estimate the impact of transporting one shipment of radioactive material over a unit distance of travel in a given population density zone. The unit risk factors were combined with routing information, such as the shipment distances in various population density zones, to determine the risk for a single shipment (a shipment risk factor) between a given origin and destination. Unit risk factors were developed on the basis of travel on interstate highways and freeways, as required by 49 CFR Parts 171 through 177 for highway-route-controlled quantities of radioactive material within rural, suburban, and urban population zones by using RADTRAN 5 and its default data. In addition, the analysis assumed that, 10 percent of the time, travel through suburban and urban zones would encounter rush-hour conditions, leading to lower average speed and higher traffic density. **Table J–5** provides an example of the unit risk factors (not specific to shipments of WNYNSC waste) for a truck and rail shipment

[6] *Note that no contact-handled transuranic waste was identified, however, this dose rate was given for completeness.*

with a Transport Index of 1 (i.e., dose rate of 1 millirem per hour at 1 meter [3.3 feet]) from the surface of the shipping container, or the conveyance. This table identifies the contributing factors to the estimated exposures considered for the crew (occupational) and the general public. Note that the size of the waste package and assumptions regarding public shielding afforded by its general housing structure within each zone would be major contributing factors in the calculated dose.

Table J–5 Incident-free Unit Risk Factors for a Dose Rate of 1 Millirem per Hour at 1 Meter from the Shipping Container for Truck and Rail Shipments

Mode	Exposure Group	Unit Risk Factors [a]		
		Rural	Suburban [b]	Urban [b]
Truck	Occupational [c] (person-rem per kilometer)	5.33×10^{-6}	5.86×10^{-6}	5.86×10^{-6}
	General Population			
	Off-link [d] (person-rem per kilometer per person per square kilometer)	2.62×10^{-9}	2.50×10^{-9}	5.18×10^{-11}
	On-link [e] (person-rem per kilometer)	7.21×10^{-7}	1.79×10^{-6}	5.66×10^{-6}
	Stops [f] (person-rem per kilometer per person per square kilometer)	2.30×10^{-10}	2.30×10^{-10}	2.30×10^{-10}
	Escorts [g] (person-rem per kilometer)	2.42×10^{-7}	2.55×10^{-7}	2.55×10^{-7}
Rail	Occupational [h] (person-rem per kilometer)	2.10×10^{-7}	2.10×10^{-7}	2.10×10^{-7}
	General Population			
	Off-link [d] (person-rem per kilometer per person per square kilometer)	3.52×10^{-9}	4.90×10^{-9}	1.69×10^{-10}
	On-link [e] (person-rem per kilometer)	8.23×10^{-9}	1.06×10^{-7}	2.94×10^{-7}
	Stops [f] (person-rem per kilometer per person per square kilometer)	8.10×10^{-10}	8.10×10^{-10}	8.10×10^{-10}
	Escorts [i] (person-rem per kilometer)	1.57×10^{-6}	2.52×10^{-6}	4.21×10^{-6}

[a] The methodology, equations, and data used to develop the unit risk factors are discussed in the *RADTRAN 5 User Manual* (Neuhauser and Kanipe 2003). The risk factors provided here are for a truck and rail cask with the following characteristic length and diameters: 5.2-meter (17.06-foot) length and 1.0-meter (3.28-foot) diameter for a truck cask, and 5.06-meter (16.6-foot) length and 2.0-meter (6.56-foot) diameter for a rail cask. Because the characteristics of transuranic waste shipment are different from those used here, the contact-handled transuranic shipment risk factors would be higher than the values given here by a factor of 1.387 and 1.756 for the population dose and crew dose, respectively.
[b] Ten percent of travel within these zones encounters rush-hour traffic with a higher traffic density and a lower speed.
[c] Maximum dose in the truck cabin (crew dose) is 2 millirem per hour, per 10 CFR 71.47, unless the crew member is a trained radiation worker, which would administratively limit the annual dose to 2 rem per year (DOE Administrative Control, DOE-STD-1098-99 [DOE 1999]).
[d] Off-link general population refers to persons within 800 meters (0.50 miles) of the transportation route. The difference in doses between the rural, suburban, and urban populations is due to the assumptions regarding public shielding afforded by its general housing structure within each zone.
[e] On-link general population refers to persons sharing the transportation route.
[f] Dose to residents from frequent stops along the routes.
[g] Escorts (two persons) in a vehicle that follows or leads the truck by 60 meters (about 200 feet). The dose to this vehicle is estimated to be 0.15 millirem per hour for a cask at the regulatory dose limit (i.e., 10 millirem per hour at 2 meters), (DOE 2002a).
[h] Need to add the nonlinear component of incident-free rail dose for crew members because of railcar inspections and classifications, which is 0.000233 person-rem per shipment. *RADTRAN 5 Technical Manual*, Appendix B (Neuhauser et al. 2000), contains an explanation of the rail exposure model.
[i] Escorts (two persons) at a distance of 30 meters (about 100 feet) from the end of the shipping cask. The dose to the escort is estimated to be 0.71 millirem per hour for a cask at the regulatory dose limit (DOE 2002a).
Note: To convert from meters to feet, multiply by 3.281.

The radiological risks from transporting the waste are estimated in terms of the number of LCFs among the crew and the exposed population. A health risk conversion factor of 0.0006 LCFs per person-rem of exposure was used for both the public and workers (DOE 2003a).

J.5.2 Nonradiological Risk

The nonradiological risks, or vehicle-related health risks, resulting from incident-free transport may be associated with the generation of air pollutants by transport vehicles during shipment and are independent of the radioactive nature of the shipment. The health endpoint assessed under incident-free transport conditions is the excess latent mortality due to inhalation of vehicle emissions. Unit risk factors for pollutant inhalation in terms of mortality have been generated (Rao et al. 1982); however, the emergence of considerable data regarding threshold values for various chemical constituents of vehicle exhaust has made linear extrapolation to estimate the risks from vehicle/rail emissions untenable (Neuhauser et al. 2000). This calculation has been dropped from RADTRAN in its recent revision (Neuhauser and Kanipe 2003). Therefore, no risk factors have been assigned to the vehicle emissions in this EIS.

J.5.3 Maximally Exposed Individual Exposure Scenarios

The maximum individual doses for routine offsite transportation were estimated for transportation workers, as well as for members of the general population.

For truck shipments, three hypothetical scenarios were evaluated to determine the MEI in the general population. These scenarios are (DOE 2002a):

- A person caught in traffic and located 1.2 meters (4 feet) from the surface of the shipping container for 30 minutes;
- A resident living 30 meters (98 feet) from the highway used to transport the shipping container; and
- A service station worker at a distance of 16 meters (52 feet) from the shipping container for 50 minutes.

The hypothetical MEI doses were accumulated over a single year for all transportation shipments. However, for the scenario involving an individual caught in traffic next to a shipping container, the radiological exposures were calculated for only one event because it was considered unlikely that the same individual would be caught in traffic next to all containers for all shipments. For truck shipments, the maximally exposed transportation worker is the driver who was assumed to have been trained as a radiation worker and to drive shipments for up to 2,000 hours per year, or accumulate an exposure of 2 rem per year. A member of the truck crew would be a non–radiation worker; the maximum annual dose rate for a non–radiation worker is 100 millirem (10 CFR 20.1301).

Three hypothetical scenarios were also evaluated for railcar shipments. They are:

- A rail yard worker working at a distance of 10 meters (33 feet) from the shipping container for 2 hours;
- A resident living 30 meters (98 feet) from the rail line where the shipping container was being transported; and
- A resident living 200 meters (656 feet) from a rail stop during classification and inspection for 20 hours.

The maximally exposed transportation worker for both truck and rail shipments is an individual inspecting the cargo at a distance of 1 meter (3.3 feet) from the shipping container for 1 hour.

J.6 Transportation Accident Risks

J.6.1 Methodology

The offsite transportation accident analysis considers the impact of accidents during the transportation of waste by truck or rail. Under accident conditions, impacts on human health and the environment could result from the release and dispersal of radioactive material. Transportation accident impacts were assessed using an accident analysis methodology developed by the NRC. This section provides an overview of the methodologies; detailed descriptions of various methodologies are found in the *Radioactive Material Transportation Study*, NUREG-0170; *Modal Study*, NUREG/CR-4829; and *Reexamination Study*, NUREG/CR-6672 (NRC 1977, 1987, 2000). Accidents that could potentially breach the shipping container are represented by a spectrum of accident severities and radioactive release conditions. Historically, most transportation accidents involving radioactive materials have resulted in little or no release of radioactive material from the shipping container. Consequently, the analysis of accident risks takes into account a spectrum of accidents ranging from high-probability accidents of low severity to hypothetical high-severity accidents that have a correspondingly low probability of occurrence. The accident analysis calculates the probabilities and consequences from this spectrum of accidents.

To provide DOE and the public with a reasonable assessment of radioactive waste transportation accident impacts, two types of analysis were performed. First, an accident risk assessment was performed that takes into account the probabilities and consequences of a spectrum of potential accident severities using a methodology developed by the NRC (NRC 1977, 1987, 2000). For the spectrum of accidents considered in the analysis, accident consequences in terms of collective "dose risk" to the population within 80 kilometers (50 miles) were determined using the RADTRAN 5 computer program (Neuhauser et al. 2000). The RADTRAN 5 code sums the product of consequences and probability over all accident severity categories to obtain a probability-weighted risk value referred to in this appendix as "dose risk," which is expressed in units of person-rem. Second, to represent the maximum reasonably foreseeable impacts to individuals and populations should an accident occur, maximum radiological consequences were calculated in an urban or suburban population zone for an accidental release with a likelihood of occurrence greater than 1-in-10 million per year using the RISKIND computer program (Yuan et al. 1995).

For accidents in which a waste container or the cask shielding was undamaged, population and individual radiation exposure from the waste package was evaluated for the duration that would be needed to recover and resume shipment. The collective dose over all segments of transportation routes was evaluated for an affected population up to a distance of 800 meters (0.5 miles) from the accident location. This dose is an external dose, and is approximately inversely proportional to the square of the distance of the affected population from accident. Any additional dose to those residing beyond 800 meters (0.5 miles) from the accident would be negligible. The dose to an individual (first responder) was calculated assuming that the individual would be located at 2 to 10 meters (6.6 to 33 feet) from the package. For the accidents leading to loss of cask shielding, a method similar to that provided in the *Reexamination Study* and adapted in the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (*Yucca Mountain EIS)* was used (NRC 2000; DOE 2002b, 2008).

J.6.2 Accident Rates

Whenever material is shipped, the possibility of a traffic accident that could result in vehicular damage, injury, or death exists. Even when drivers are trained in defensive driving and taking great care, there is a risk of a traffic accident. To date, DOE and its predecessor agencies have a successful 50-year history in transporting radioactive materials. In the years of moving radioactive and hazardous materials, DOE has not had a single fatality related to the hazardous or radioactive material cargo (DOE 2009).

For the calculation of accident risks, vehicle accident and fatality rates were taken from data provided in *State-Level Accident Rates for Surface Freight Transportation: A Reexamination*, ANL/ESD/TM-150 (Saricks and Tompkins 1999). Accident rates are generically defined as the number of accident involvements (or fatalities) in a given year per unit of travel in that same year. Therefore, the rate is a fractional value, with accident involvement count as the numerator of the fraction and vehicular activity (total travel distance in truck kilometers) as its denominator. Accident rates were generally determined for a multi-year period. For assessment purposes, the total number of expected accidents or fatalities was calculated by multiplying the total shipment distance for a specific case by the appropriate accident or fatality rate. No reduction in accident or fatality rates was assumed even though radioactive material carrier drivers are better trained and have better-maintained equipment.

For truck transportation, the rates presented are specifically for heavy-haul combination trucks involved in interstate commerce (Saricks and Tompkins 1999). Heavy-haul combination trucks are rigs composed of a separable tractor unit containing the engine and one to three freight trailers connected to each other. Heavy-haul combination trucks are typically used for radioactive material shipments. Truck accident rates were computed for each state based on statistics compiled by the Federal Highway Administration, Office of Motor Carriers, from 1994 to 1996. A fatality caused by an accident is the death of a member of the public who is killed instantly or dies within 30 days due to injuries sustained in the accident.

For offsite transportation, the accident and fatality rates for this EIS are based on the state-level data provided in the Saricks and Tompkins report, ANL/ESD/TM-150 (Saricks and Tompkins 1999). The rates in the Saricks and Tompkins report are given in terms of accident and fatality per car-kilometer and railcar-kilometer traveled. The selected accident and fatality rates used in this EIS are limited to the rates in those states where trucks and rails would traverse transporting wastes from the WNYNSC to the designated disposal sites. For trucks, the selected state-level rates are those associated with accidents and fatalities on interstate highways.

Recent review of the truck accidents and fatalities reports by the Federal Carrier Safety Administration indicated that state-level accidents and fatalities were underreported. For the years 1994 through 1996, which were the basis for the analysis in the Saricks and Tompkins report, a review identified that accidents were underreported by about 39 percent and fatalities were underreported by about 36 percent (UMTRI 2003). Therefore, state-level truck accident and fatality rates in the Saricks and Tompkins report were increased by factors of 1.64 and 1.57, respectively, in this Final EIS to account for the underreporting. For each rail shipment, it was assumed that each train would consist of at least three cars: a locomotive, a crew car, and a rail car carrying waste.

For local and regional transport, New York State accident and fatality rates were used. The data were provided in ANL/ESD/TM-150 (Saricks and Tompkins 1999). The rates used were 3.45 accidents per 10 million truck kilometers and 1.24 fatalities per 100 million truck kilometers.

J.6.3 Accident Severity Categories and Conditional Probabilities

Accident severity categories for potential radioactive waste transportation accidents are described in the *Radioactive Material Transportation Study* (NRC 1977) for radioactive waste in general, the *Modal Study* (NRC 1987), and the *Reexamination Study* (NRC 2000) for spent nuclear fuel. The methods described in the *Modal Study* and the *Reexamination Study* are applicable to transportation of radioactive materials in a Type B spent fuel cask. The accident severity categories presented in the *Radioactive Material Transportation Study* would be applicable to all other waste transported off site.

The *Radioactive Material Transportation Study* (NRC 1977) originally was used to estimate conditional probabilities associated with accidents involving transportation of radioactive materials. The *Modal Study* and the *Reexamination Study* (NRC 1987, 2000) are initiatives taken by the NRC to refine more precisely the analysis presented in *Radioactive Material Transportation Study* for spent nuclear fuel shipping casks.

Whereas the *Radioactive Material Transportation Study* (NRC 1977) analysis was primarily performed using best engineering judgments and presumptions concerning cask response, the later studies relied on sophisticated structural and thermal engineering analysis and a probabilistic assessment of the conditions that could be experienced in severe transportation accidents. The latter results are based on representative spent nuclear fuel casks assumed to have been designed, manufactured, operated, and maintained according to national codes and standards. Design parameters of the representative casks were chosen to meet the minimum test criteria specified in 10 CFR Part 71. The study is believed to provide realistic, yet conservative, results for radiological releases under transport accident conditions.

In both the *Modal Study* and the *Reexamination Study*, potential accident damage to a cask is categorized according to the magnitude of the mechanical forces (impact) and thermal forces (fire) to which a cask may be subjected during an accident. Because all accidents can be described in these terms, severity is independent of the specific accident sequence. In other words, any sequence of events that results in an accident in which a cask is subjected to forces within a certain range of values is assigned to the accident severity region associated with that range. The accident severity scheme is designed to take into account all potential foreseeable transportation accidents, including accidents with low probability but high consequences, and those with high probability but low consequences.

As discussed earlier, the accident consequence assessment considers the potential impacts of severe transportation accidents. In terms of risk, the severity of an accident must be viewed in terms of potential radiological consequences, which are directly proportional to the fraction of the radioactive material within a cask that is released to the environment during the accident. Although accident severity regions span the entire range of mechanical and thermal accident loads, they are grouped into accident categories that can be characterized by a single set of release fractions and are, therefore, considered together in the accident consequence assessment. The accident category severity fraction is the sum of all conditional probabilities in that accident category.

For the accident risk assessment, accident “dose risk” was generically defined as the product of the consequences of an accident and the probability of occurrence of that accident, an approach consistent with the methodology used by RADTRAN 5 computer code. The RADTRAN 5 code sums the product of consequences and probability over all accident categories to obtain a probability-weighted risk value referred to in this appendix as “dose risk,” which is expressed in units of person-rem.

J.6.4 Atmospheric Conditions

Because it is impossible to predict the specific location of an offsite transportation accident, generic atmospheric conditions were selected for the risk and consequence assessments. On the basis of observations from National Weather Service surface meteorological stations at over 177 locations in the United States, on an annual average, neutral conditions (Pasquill Stability Classes C and D) occur 58.5 percent of the time, and stable (Pasquill Stability Classes E, F, and G) and unstable (Pasquill Stability Classes A and B) conditions occur 33.5 percent and 8 percent of the time, respectively (DOE 2002a). The neutral weather conditions dominate in each season, but most frequently in the winter (nearly 60 percent of the observations).

Neutral weather conditions (Pasquill Stability Class D) are the most frequently occurring atmospheric stability condition in the United States and are thus most likely to be present in the event of an accident involving a radioactive waste shipment. Neutral weather conditions are typified by moderate windspeeds, vertical mixing within the atmosphere, and good dispersion of atmospheric contaminants. Stable weather conditions are typified by low windspeeds, very little vertical mixing within the atmosphere, and poor dispersion of atmospheric contaminants. The atmospheric condition used in RADTRAN 5 is an average weather condition that corresponds to a stability class spread between Class D (for near distance) and Class E (for farther distance).

The accident consequences for the maximum reasonably foreseeable accident (an accident with likelihood of occurrence greater than 1 in 10 million per year) were assessed under both stable (Class F with a wind speed of 1 meter [3.3 feet] per second) and neutral (Class D with a wind speed of 4 meters [13 feet] per second) atmospheric conditions. The population dose is evaluated under neutral atmospheric conditions and the MEI dose under stable atmospheric conditions. The MEI dose would represent an accident under worst-case weather conditions (stable condition, with minimum diffusion and dilution). The population dose would represent an average weather condition.

J.6.5 Radioactive Release Characteristics

Radiological consequences were calculated by assigning radionuclide release fractions on the basis of the type of waste, the type of shipping container, and the accident severity category. The release fraction is defined as the fraction of the radioactivity in the container that could be released to the atmosphere in a given severity of accident. Release fractions vary according to waste type and the physical or chemical properties of the radioisotopes. Most solid radionuclides are nonvolatile and are, therefore, relatively nondispersible.

Representative release fractions were developed for each waste and container type on the basis of DOE and NRC reports (DOE 1994, 2002b, 2003a; NRC 1977, 2000). The severity categories and corresponding release fractions provided in these documents cover a range of accidents from no impact (zero speed) to impacts with speeds in excess of 193 kilometers (120 miles) per hour onto an unyielding surface. Traffic accidents that could occur at the site would be of minor impact due to lower local speed, with no release potential.

For radioactive wastes transported in a Type B cask, the particulate release fractions were developed consistent with the models in the *Reexamination Study* (NRC 2000) and adapted in the *West Valley Demonstration Project Waste Management Environmental Impact Statement* (DOE 2003b). For wastes transported in Type A containers (e.g., 208-liter [55-gallon] drums and boxes), the fractions of radioactive material released from the shipping container were based on recommended values from *Radioactive Material Transportation Study* and *DOE Handbook on Airborne Release and Respirable Fractions* (NRC 1977, DOE 1994). For contact-handled and remote-handled transuranic waste, the release fractions corresponding to the *Radioactive Material Transportation Study* severity categories as adapted in the *WIPP SEIS* were used (DOE 1997, 2002b). For wastes transported in high integrity containers, and lift liners in intermodal (or Sealand) containers, release fractions were calculated using a method similar to that used in the *WIPP SEIS*.

For those accidents where the waste container or cask shielding was undamaged and no radioactive material released, it was assumed that it would take 12 hours to recover from the accident and resume shipment. During this period, no individual would remain close to the cask. A first responder could stay at a location 2 to 10 meters (6.6 to 33 feet) from the package, at a position where the dose rate would be the highest, for 30 minutes in a loss of shielding accident, and 1 hour for other accidents with no release (DOE 2002b).

J.6.6 Acts of Sabotage or Terrorism

In the aftermath of the events of September 11, 2001, DOE is continuing to assess measures to minimize the risk or potential consequences of radiological sabotage. While it is not possible to determine terrorists' motives and targets with certainty, DOE considers the threat of terrorist attack to be real, and makes all efforts to reduce any vulnerability to this threat.

Nevertheless, DOE has evaluated the impacts of acts of sabotage and terrorism on transportation of spent nuclear fuel and high-level radioactive waste shipments (DOE 1996, 2002a). The spectrum of accidents considered ranges from a direct attack on the cask from afar to hijacking and exploding the shipping cask in an urban area. Both of these actions would result in damaging the cask and its contents and releasing radioactive materials. The fraction of the materials released is dependent on the nature of the attack (type of explosive or weapon used). The sabotage event evaluated in the *Yucca Mountain EIS* was considered as the enveloping analysis for this EIS. The event was assumed to involve either a truck-sized, or a rail-sized cask containing light water reactor spent nuclear fuel. The consequences of such an act were calculated to result in an MEI dose (at 140 meters [460 feet]) of 40 to 110 rem for events involving a rail-sized or truck-sized cask, respectively. These events would lead to an increase in risk of fatal cancer to the MEI by 2 to 7 percent (DOE 2002a). The quantity of radioactive materials transported under all decommissioning alternatives considered here would be less than that considered in this analysis. Therefore, estimates of risk in the *Yucca Mountain EIS* envelop the risks from an act of sabotage or terrorism involving the radioactive material transported under all alternatives considered in this EIS.

J.7 Risk Analysis Results

Per-shipment risk factors have been calculated for the collective populations of exposed persons and for the crew for all anticipated routes and shipment configurations. Radiological risks are presented in doses per shipment for each unique route, material, and container combination. Radiological risk factors per shipment for incident-free transportation and accident conditions are presented in **Table J–6**. For incident-free transportation, both dose and LCF risk factors are provided for the crew and exposed population. The radiological risks would result from potential exposure of people to external radiation emanating from the packaged waste. The exposed population includes the off-link public (i.e., people living along the route), on-link public (i.e., pedestrian and car occupants along the route), and public at rest and fuel stops.

Risk factors are given for both radiological, transportation accidents in terms of potential LCFs in the exposed population, and nonradiological, accidents in terms of the number of traffic fatalities. LCFs represent the number of additional latent fatal cancers among the exposed population. Under accident conditions, the population would be exposed to radiation from released radioactivity if the package is damaged, and would receive a direct dose if the package is unbreached. For the accidents with no release, the analysis conservatively assumed that it would take about 12 hours to remove the package and/or vehicle from the accident area (DOE 2002a). Accidents leading to a loss of cask shielding would only be applicable to those shipments that use shielded casks, such as shipments of Greater-Than-Class C, remote-handled Class C, and remote-handled transuranic wastes.

As indicated in this table, all risk factors are less than one. This means that no LCFs or traffic fatalities are expected to occur during each transport. For example, the risk factors to truck crew and population for transporting one shipment of Class B and Class C waste to NTS are given as 3.8×10^{-4} and 1.2×10^{-4} LCFs, respectively. This risk can also be interpreted as meaning that there is a chance of 1 in 2,600 that an additional latent fatal cancer could be experienced among the exposed workers from exposure to radiation during one shipment of Class B and Class C waste to Nevada. Similarly, there is a chance of 1 in 8,300 that an additional latent fatal cancer could be experienced among the exposed population residing along the transport route. These are essentially equivalent to zero risk. It should be noted that the maximum allowable dose rate in the truck cabin is less than or equal to 2 millirem per hour, and the maximum annual dose to a commercial truck driver is 100 millirem per year, unless the individual is a trained radiation worker who would have an administrative annual dose limit of 2 rem (DOE 1999). The values could be higher if drivers are radiation workers operating under a Federal or state-licensed program (49 CFR 173.441). An individual receiving a dose of 100 millirem would have an expected risk of developing a latent fatal cancer of 6.0×10^{-5}. The same individual is expected to receive a dose of about 620 millirem per year on average from ubiquitous background and other sources of radiation (NCRP 2009).

Table J–6 Risk Factors per Shipment of Radioactive Waste

		Incident-Free				*Accident*	
Waste Materials and Mode of Transport	***Transport Destination***	***Crew Dose (person-rem)***	***Crew Risk (LCF)***	***Population Dose (person-rem)***	***Population Risk (LCF)***	***Radiological Risk (LCF)***	***Non-radiological Risk (traffic fatalities)***
Truck Shipments							
Class A (B) [a]	NTS	7.9×10^{-2}	4.7×10^{-5}	2.5×10^{-2}	1.5×10^{-5}	4.7×10^{-10}	7.6×10^{-5}
Class A (D) [b]		9.4×10^{-2}	5.7×10^{-5}	4.2×10^{-2}	2.5×10^{-5}	7.4×10^{-10}	7.6×10^{-5}
Class B and Class C [c]		6.3×10^{-1}	3.8×10^{-4}	2.0×10^{-1}	1.2×10^{-4}	8.0×10^{-8}	7.6×10^{-5}
Class C (RH) [d]		5.5×10^{-1}	3.3×10^{-4}	6.9×10^{-2}	4.2×10^{-5}	9.9×10^{-10}	7.6×10^{-5}
Low specific activity		4.3×10^{-3}	2.6×10^{-6}	8.7×10^{-4}	5.2×10^{-7}	1.5×10^{-10}	7.6×10^{-5}
GTCC [e]	NTS [f]	3.4×10^{-2}	2.1×10^{-5}	4.3×10^{-3}	2.6×10^{-6}	2.0×10^{-9}	7.6×10^{-5}
GTCC [g]		3.2×10^{-1}	1.9×10^{-4}	9.0×10^{-2}	5.4×10^{-5}	4.8×10^{-9}	7.6×10^{-5}
Low specific activity	EnergySolutions	3.6×10^{-3}	2.1×10^{-6}	7.1×10^{-4}	4.3×10^{-7}	2.5×10^{-10}	9.8×10^{-5}
Class A (B) [a]		6.5×10^{-2}	3.9×10^{-5}	2.0×10^{-2}	1.2×10^{-5}	8.2×10^{-10}	9.8×10^{-5}
Class A (D) [b]		7.8×10^{-2}	4.7×10^{-5}	3.5×10^{-2}	2.1×10^{-5}	1.3×10^{-9}	9.8×10^{-5}
Class B and Class C [h]	Barnwell	3.5×10^{-1}	2.1×10^{-4}	2.0×10^{-2}	1.2×10^{-5}	1.1×10^{-6}	8.2×10^{-5}
Class C (RH) [d]		2.1×10^{-1}	1.3×10^{-4}	2.8×10^{-2}	1.7×10^{-5}	2.1×10^{-9}	8.2×10^{-5}
RH-TRU	WIPP [i]	1.4×10^{-1}	8.3×10^{-5}	2.1×10^{-2}	1.3×10^{-5}	1.2×10^{-9}	1.0×10^{-4}
Class B and Class C [h]	Hanford Site [j]	9.3×10^{-1}	5.6×10^{-4}	5.2×10^{-2}	3.1×10^{-5}	1.4×10^{-6}	1.3×10^{-4}
Class C (RH) [d]		5.7×10^{-1}	3.4×10^{-4}	7.1×10^{-2}	4.3×10^{-5}	2.0×10^{-9}	1.3×10^{-4}
Rail Shipments							
Class A (B) [a]	NTS	7.0×10^{-3}	4.2×10^{-6}	1.1×10^{-2}	6.6×10^{-6}	3.9×10^{-10}	2.8×10^{-4}
Class A (D) [b]		6.3×10^{-3}	3.8×10^{-6}	8.9×10^{-3}	5.4×10^{-6}	4.4×10^{-10}	2.8×10^{-4}
Class B and Class C [c]		5.6×10^{-2}	3.3×10^{-5}	8.7×10^{-2}	5.2×10^{-5}	5.8×10^{-8}	2.8×10^{-4}
Class C (RH) [d]		4.0×10^{-2}	2.4×10^{-5}	4.6×10^{-2}	2.8×10^{-5}	1.5×10^{-9}	2.8×10^{-4}
Low specific activity		2.8×10^{-4}	1.7×10^{-7}	3.5×10^{-4}	2.1×10^{-7}	1.3×10^{-10}	2.8×10^{-4}
GTCC [e]	NTS [f]	2.5×10^{-3}	1.5×10^{-6}	2.9×10^{-3}	1.7×10^{-6}	3.4×10^{-9}	2.8×10^{-4}
GTCC [g]		3.5×10^{-2}	2.1×10^{-5}	4.0×10^{-2}	2.4×10^{-5}	8.1×10^{-9}	2.8×10^{-4}
Low specific activity	EnergySolutions	2.3×10^{-4}	1.4×10^{-7}	3.5×10^{-4}	2.1×10^{-7}	1.7×10^{-10}	2.8×10^{-4}
Class A (B) [a]		5.7×10^{-3}	3.4×10^{-6}	1.1×10^{-2}	6.5×10^{-6}	5.0×10^{-10}	2.8×10^{-4}
Class A (D) [b]		5.1×10^{-3}	3.1×10^{-6}	8.8×10^{-3}	5.3×10^{-6}	5.6×10^{-10}	2.8×10^{-4}
Class B and Class C [h]	Barnwell	1.6×10^{-2}	9.4×10^{-6}	2.5×10^{-2}	1.5×10^{-5}	7.5×10^{-7}	3.9×10^{-4}
Class C (RH) [d]		1.9×10^{-2}	1.2×10^{-5}	3.8×10^{-2}	2.3×10^{-5}	2.5×10^{-9}	3.9×10^{-4}
RH-TRU	WIPP [i]	9.1×10^{-3}	5.4×10^{-6}	1.3×10^{-2}	7.8×10^{-6}	6.0×10^{-10}	3.1×10^{-4}
Class B and Class C [h]	Hanford Site [j]	3.2×10^{-2}	1.9×10^{-5}	3.2×10^{-2}	1.9×10^{-5}	1.2×10^{-6}	4.4×10^{-4}
Class C (RH) [d]		3.9×10^{-2}	2.4×10^{-5}	4.8×10^{-2}	2.9×10^{-5}	2.9×10^{-9}	4.4×10^{-4}

GTCC = Greater-Than-Class C, LCF = latent cancer fatality, NTS = Nevada Test Site, RH = remote-handled, TRU = transuranic, WIPP = Waste Isolation Pilot Plant.

[a] Class A low-level radioactive waste transported in Type A B-25 boxes.

[b] Class A low-level radioactive waste transported in 208-liter (55-gallon) drums.

[c] Class B and Class C wastes are transported to NTS in Type A B-25 boxes. Because these wastes have similar external dose rate and could be transported on the same truck or rail, a single radiological accident risk factor that maximizes the hazards is provided.

[d] Remote-handled Class C wastes are transported in 208-liter (55-gallon) drums.

[e] Greater-Than-Class C waste other than fuel and hardware described in footnote g.

[f] For purposes of analysis only, Greater-Than-Class C waste is assumed to be shipped to NTS. Any decision on disposal of WVDP Greater-Than-Class C low-level radioactive waste must await the analysis contained in and decisions resulting from the *Disposal of Greater-Than-Class C Low-Level Radioactive Waste Environmental Impact Statement* (DOE/EIS-0375).

[g] Greater-Than-Class C waste includes the unprocessed irradiated fuel and the hulls and hardware from the processed fuel.

[h] Class B and Class C low-level radioactive wastes are transported to this site in high-integrity containers.

[i] For purposes of analysis only, it is assumed that transuranic waste would be shipped to WIPP. A disposal facility for potential non-defense transuranic waste is currently being evaluated in the *Disposal of Greater-Than-Class C Low-Level Radioactive Waste Environmental Impact Statement* (DOE/EIS-0375).

[j] This site is used as a proxy for shipment of commercial Class B and Class C wastes to a western U.S. disposal facility.

Transportation risks were calculated assuming that wastes are transported using either all rail or all truck. DOE could decide to use a combination of both truck and rail for transporting wastes to any of the disposal site options. Shipments involving a combination of rail and truck for a specific shipment would involve workers who would transfer waste containers from railcars to trucks (or vice versa) at an intermodal station. Based on a study of total risk to workers and population from truck-only transportation and a combination of truck-rail transportation (PNNL 1999), it is estimated that the total dose to workers and public for a combination of rail and truck shipment is less than would occur if the entire transportation occurred on truck. The accident and fatality rates are per truck-kilometer or railcar-kilometer.

Table J–7 provides the estimated number of shipments for various wastes under all alternatives and waste disposal site options. The shipment numbers were calculated using the estimated waste volumes for each waste type as given in Appendix C and summarized in Section 4.1.7 of this EIS, and the waste container and shipment characteristics provided in Table J–2. The shipment numbers are for truck transport of various wastes for the DOE/Commercial Disposal Option (where DOE wastes are disposed of at DOE facilities and commercial wastes are sent to commercial facilities) and the Commercial Disposal Option (where only commercial disposal options were assumed). Some of the wastes would be sent to commercial sites irrespective of the disposal site option considered. In the commercial disposal site option, there is no disposition for transuranic and Greater-Than-Class C wastes; no commercial disposal sites are available for these wastes. As explained earlier, a disposal facility for Greater-Than-Class C low-level radioactive waste and potential non-defense transuranic waste will be determined through the Record of Decision for the *GTCC EIS* (DOE/EIS-0375). However, for purposes of analysis only, in this EIS, it was assumed that these wastes would be transported to NTS and WIPP, respectively.

Both the radiological dose risk factor and nonradiological risk factor for transportation accidents are presented in Table J–6. The radiological and nonradiological accident risk factors are provided in terms of potential fatalities per shipment. The radiological risks are in terms of LCFs. For the population, the radiological risks were calculated by multiplying the accident dose risks by the health risk factor of 6×10^{-4} cancer fatalities per person-rem of exposure. The nonradiological risk factors are non-occupational traffic fatalities resulting from transportation accidents.

As discussed in Section J.6.3, the accident dose is called “dose risk” because the values incorporate the spectrum of accident severity probabilities and associated consequences (e.g., dose). The accident dose risks are very low because accident severity probabilities (i.e., the likelihood of accidents leading to confinement breach of a package or shipping cask and release of its contents) are small, and the content and form of the wastes (solid dirt-like contamination) are such that they would lead to nondispersible and mostly noncombustible release. Although persons reside within an 80-kilometer (50-mile) radius along the transportation route, they are generally quite far from the route. Because RADTRAN 5 uses an assumption of homogeneous population, it would greatly overestimate the actual doses.

Table J–8 shows the risks of transporting radioactive waste under each alternative. In this table, Barnwell is used as an eastern proxy site for disposal of commercial Class B and C wastes. **Table J–9** shows the risks of transporting radioactive wastes under each alternative considering the Hanford Site as a western proxy site for disposal of commercial Class B and C waste. The risks are calculated by multiplying the previously given per-shipment factors by the number of shipments over the duration of the program and, for radiological doses, by the health risk conversion factors. The risks are for the total offsite transport of the radioactive wastes over the entire period under each alternative. Review of the sequence of activities under each alternative indicates that, except for the Sitewide Removal Alternative where activities would constantly generate waste requiring offsite transport over a period of about 60 years, the duration of intensive waste generating activities under other alternatives would be less than 10 years. These activities would occur at the beginning of implementation of the alternatives.

Table J–7 Estimated Number of Truck Shipments Under Each Alternative

Number of Shipments					
DOE/Commercial Disposal Option					
Waste Types	***Assumed Disposal Location***	***Removal Alternative***	***Close-In-Place Alternative***	***Phased Decisionmaking Alternative (Phase 1)***	***No Action Alternative*** [i]
Low specific activity	NTS/EnergySolutions [j]	92,263	831	10,799	151
Class A (B) [a]	NTS/EnergySolutions [j]	8,212	288	1,473	470
Class A (D) [b]	NTS/EnergySolutions [j]	46	5	29	1
Class B and C [c]	NTS/Commercial [j]	924	0	80	0
Class C (RH) [d]	NTS/Commercial [j]	124	34	20	0
Mixed LLW	EnergySolutions	40	28	3	1
GTCC [e]	Nevada Test Site	2,357	0	0	0
Transuranic [f]	Waste Isolation Pilot Plant	477	17	335	0
Hazardous [g]	Local	2	1	1	2
Other [h]	Local	8,881	1,003	2,155	43
Commercial Disposal Option					
Waste Types	***Assumed Disposal Location***	***Removal Alternative***	***Close-In-Place Alternative***	***Phased Decisionmaking Alternative (Phase 1)***	***No Action Alternative*** [i]
Low specific activity	EnergySolutions	92,263	830	10,799	151
Class A (B) [a]	EnergySolutions	8,211	287	1,473	470
Class A (D) [b]	EnergySolutions	46	5	28	1
Class B and C [c]	Commercial	1,075	0	224	0
Class C (RH) [d]	Commercial	124	33	20	0
Mixed LLW	EnergySolutions	40	28	3	1
GTCC [e]	Nevada Test Site	2,357	0	0	0
Transuranic [f]	Waste Isolation Pilot Plant	477	17	335	0
Hazardous [g]	Local	2	1	1	2
Other [h]	Local	8,881	1,003	2,155	43

GTCC = Greater-Than-Class C, LLW = low-level radioactive waste, RH = remote-handled.

[a] Class A low-level radioactive waste transported in Type A B-25 boxes.

[b] Class A low-level radioactive waste transported in 208-liter (55-gallon) drums.

[c] For the purposes of analysis, for the Commercial Disposal Option, all Class B and C contact-handled wastes are assumed to be packaged in high-integrity containers for transport to either an eastern or a western United States disposal site (i.e., Barnwell or Hanford). For the DOE/Commercial Disposal Option, all commercial Class B and C contact-handled wastes are assumed to be packaged in high-integrity containers for transport to either an eastern or a western United States disposal site, while DOE Class B and C contact-handled wastes are assumed to be packaged in Type A B-25 boxes for transport to NTS.

[d] Class C remote-handled wastes packaged in drums or high-integrity containers and transported in Type B casks. Class B wastes packaged in drums are also transported in Type B casks.

[e] For purposes of analysis only, Greater-Than-Class C waste is assumed to be shipped to NTS. Any decision on disposal of WVDP Greater-Than-Class C low-level radioactive waste must await the analysis contained in and decisions resulting from the *Disposal of Greater-Than-Class C Low-Level Radioactive Waste Environmental Impact Statement* (DOE/EIS-0375).

[f] For purposes of analysis only, it is assumed that transuranic waste would be shipped to WIPP. A disposal facility for potential non-defense transuranic waste is currently being evaluated in the *Disposal of Greater-Than-Class C Low-Level Radioactive Waste Environmental Impact Statement* (DOE/EIS-0375).

[g] Hazardous waste would be disposed of at landfills within 160 kilometers (100 miles) of the site.

[h] This includes construction/demolition debris or other wastes that go to local landfills within about 160 kilometers (100 miles) of the site.

[i] Under the No Action Alternative, waste is generated both annually and periodically. Here, for the purposes of comparison to other alternatives, waste shipments are given for monitoring and maintenance activities over a 20-year period, which would continue to recur in 20-year cycles.

[j] DOE waste would go to NTS, or to EnergySolutions, or another appropriate commercial facility. Commercial waste would only go to EnergySolutions or another appropriate commercial facility because commercial wastes cannot be disposed of in a DOE facility.

Note: The values given in this table are for truck shipments. Rail shipments were assumed to be one-half of the number of truck shipments because each rail shipment was assumed to carry twice as much waste as a truck shipment.

Table J–8 Risks of Transporting Radioactive Waste Under Each Alternative [a] (using Barnwell as the eastern U.S. proxy site for commercial Class B and C waste disposal)

Disposal Option	Transport Mode	Number of Shipments	One-way Kilometers Traveled (million)	Incident-Free				Accident	
				Crew		Population			
				Dose (person-rem)	Risk [b]	Dose (person-rem)	Risk [b]	Radiological Risk [b]	Non-radiological Risk [b]
Sitewide Removal Alternative									
DOE/ Commercial	Truck	104,443	356.1	1,578.7	0.95	343.1	0.21	9.3×10^{-4}	9.7
	Rail	52,224	190.2	58.5	0.035	91.3	0.055	3.3×10^{-4}	14.7
Commercial	Truck	104,593	341.1	1,523.2	0.91	313.0	0.19	1.2×10^{-3}	10.2
	Rail	52,299	180.1	54.8	0.033	89.9	0.054	4.2×10^{-4}	14.7
Sitewide Close-In-Place Alternative									
DOE/ Commercial	Truck	1,203	4.3	44.3	0.027	10.5	0.0063	4.2×10^{-7}	0.10
	Rail	604	2.3	1.8	0.0011	2.8	0.0017	1.7×10^{-7}	0.17
Commercial	Truck	1,200	3.9	33.3	0.02	8.5	0.0051	5.6×10^{-7}	0.12
	Rail	602	2.1	1.4	0.00085	2.6	0.0016	2.0×10^{-7}	0.17
Phased Decisionmaking Alternative – Phase 1									
DOE/ Commercial	Truck	12,739	49.6	273.1	0.16	71.5	0.043	9.2×10^{-6}	1.0
	Rail	6,371	27.3	10.9	0.0065	16.3	0.0098	3.4×10^{-6}	1.8
Commercial	Truck	12,882	41.8	265.9	0.16	51.1	0.031	2.4×10^{-4}	1.3
	Rail	6,442	22.0	9.0	0.0054	15.3	0.0092	8.6×10^{-5}	1.8
No Action Alternative [c]									
DOE/ Commercial	Truck	623	2.4	37.8	0.023	11.8	0.0071	2.4×10^{-7}	0.05
	Rail	313	1.4	1.7	0.0010	2.6	0.0016	1.0×10^{-7}	0.09
Commercial	Truck	623	2.0	31.3	0.019	9.8	0.0059	4.3×10^{-7}	0.06
	Rail	313	1.1	1.4	0.0008	2.6	0.0016	1.3×10^{-7}	0.09

[a] For purposes of analysis only, the Greater-Than-Class C and transuranic wastes are assumed to be shipped to NTS and WIPP, respectively. A disposal facility for Greater-Than-Class C low-level radioactive waste and potential non-defense transuranic waste will be evaluated in the *Disposal of Greater-Than-Class C Low-Level Radioactive Waste Environmental Impact Statement* (DOE/EIS-0375).
[b] Risk is expressed in terms of LCFs, except for the nonradiological risk, where it refers to the number of traffic accident fatalities.
[c] Under the No Action Alternative, for the purposes of comparisons to other alternatives, transportation impacts are provided for monitoring and maintenance activities over a 20-year period.
Note: To convert kilometers to miles, multiply by 0.62137.

Tables J–7 and J–8 indicate that the maximum risk is associated with the Sitewide Removal Alternative, followed by Phase 1 of the Phased Decisionmaking Alternative, and the Sitewide Close-In-Place Alternative. The duration of decommissioning activities analyzed for the latter two alternatives is 7 and 8 years, respectively, followed by long-term sitewide monitoring and maintenance for the Close-In-Place Alternative and annual monitoring for 22 years for Phase 1 of the Phased Decisionmaking Alternative. For the Sitewide Close-In-Place Alternative, the long-term maintenance contribution over 53 years[7] following decommissioning activities includes: about 41 percent of shipments, about 17 percent of population dose, 14.5 percent of transportation worker dose, and between 38 and 40 percent of traffic fatalities; this translates to less than 0.002 fatalities per year. In Phase 1 of the Phased Decisionmaking Alternative, the contribution from temporary maintenance would be small.

[7] *For the purposes of analysis, the time period analyzed for the Close-In-Place Alternative is assumed to be 60 years. Long-term monitoring and maintenance (stewardship) would continue in perpetuity with very small annual transportation risks to members of the general public.*

Table J–9 Risks of Transporting Radioactive Waste Under Each Alternative [a] (using the Hanford Site as the western U.S. proxy site for commercial Class B and C waste disposal)

Disposal Option	Transport Mode	Number of Shipments	One-way Kilometers Traveled (million)	Incident-Free				Accident	
				Crew		Population			
				Dose (person-rem)	Risk [b]	Dose (person-rem)	Risk [b]	Radiological Risk [b]	Non-radiological Risk [b]
Sitewide Removal Alternative									
DOE/ Commercial	Truck	104,443	356.8	2,074.5	1.2	369.8	0.22	1.2×10^{-3}	9.7
	Rail	52,224	190.5	65.4	0.039	94.3	0.057	5.4×10^{-4}	14.8
Commercial	Truck	104,593	342.1	2,196.8	1.3	351.9	0.21	1.6×10^{-3}	10.2
	Rail	52,299	180.5	64.7	0.039	94.3	0.057	6.8×10^{-4}	14.8
Sitewide Close-In-Place Alternative									
DOE/ Commercial	Truck	1,203	4.3	48.6	0.029	11.0	0.0066	4.2×10^{-7}	0.10
	Rail	604	2.3	1.9	0.0012	2.8	0.0017	1.5×10^{-7}	0.17
Commercial	Truck	1,200	3.9	45.1	0.027	9.9	0.0060	5.6×10^{-7}	0.12
	Rail	602	2.1	1.4	0.00085	2.6	0.0016	2.0×10^{-7}	0.17
Phased Decisionmaking Alternative – Phase 1									
DOE/ Commercial	Truck	12,739	49.6	273.1	0.16	71.5	0.043	9.2×10^{-6}	1.0
	Rail	6,371	27.3	10.9	0.0065	16.3	0.0098	3.4×10^{-6}	1.8
Commercial	Truck	12,882	42.0	397.0	0.24	58.1	0.035	3.2×10^{-4}	1.3
	Rail	6,442	22.1	10.8	0.0065	16.1	0.0097	1.4×10^{-4}	1.8
No Action Alternative [c]									
DOE/ Commercial	Truck	623	2.4	37.8	0.023	11.8	0.0071	2.4×10^{-7}	0.05
	Rail	313	1.4	1.7	0.0010	2.6	0.0016	1.0×10^{-7}	0.09
Commercial	Truck	623	2.0	31.3	0.019	9.8	0.0059	4.3×10^{-7}	0.06
	Rail	313	1.1	1.4	0.0008	2.6	0.0016	1.3×10^{-7}	0.09

[a] For purposes of analysis only, the Greater-Than-Class C and transuranic wastes are assumed to be shipped to NTS and WIPP, respectively. A disposal facility for Greater-Than-Class C low-level radioactive waste and potential non-defense transuranic waste will be evaluated in the *Disposal of Greater-Than-Class C Low-Level Radioactive Waste Environmental Impact Statement* (DOE/EIS-0375).
[b] Risk is expressed in terms of LCFs, except for the nonradiological risk, where it refers to the number of traffic accident fatalities. Accident dose risk can be calculated by dividing the risk values by 0.0006 (DOE 2003a).
[c] Under the No Action Alternative, for the purposes of comparisons to other alternatives, transportation impacts are provided for monitoring and maintenance activities over a 20-year period.
Note: To convert kilometers to miles, multiply by 0.62137.

The values presented in Tables J–8 and J–9 show that the total radiological risks (the product of consequence and frequency) are very small under all alternatives. It should be noted that the maximum annual dose to a transportation worker would be limited to 100 millirem per year, unless the individual is a trained radiation worker who would have an administrative annual dose limit of 2 rem (DOE 1999).[8] The potential for a trained radiation worker to develop a latent fatal cancer from the maximum annual exposure is 0.0012. Therefore, no individual transportation worker would be expected to develop a latent fatal cancer from exposures during the activities under all alternatives.

[8] *A DOE transportation contractor may choose another dose limit for workers, but this dose is limited to 5 rem per year per 10 CFR 20.1201.*

Nonradiological accident risks (the potential for fatalities as a direct result of traffic accidents) present the greatest risks. Considering that the transportation activities analyzed in this EIS would occur over periods ranging from 7 to 60 years and that the average number of traffic fatalities in the United States is about 40,000 per year (NHTSA 2006), the traffic fatality risk under all alternatives would be very small.

The risks to various exposed individuals under incident-free transportation conditions have been estimated for hypothetical exposure scenarios identified in Section J.5.3. The estimated doses to workers and the public are presented in **Table J–10**. Doses are presented on a per-event basis (person-rem per event, per exposure, or per shipment), as it is generally unlikely that the same person would be exposed to multiple events. For those individuals that could have multiple exposures, the cumulative dose could be calculated. The maximum dose to a crew member is based on the same individual being responsible for driving every shipment for the duration of the campaign. Note that the potential exists for larger individual exposures under one-time events of a longer duration. For example, the dose to a person stuck in traffic next to a shipment of Class B or Class C wastes for 30 minutes is calculated to be 0.026 rem (26 millirem). This is generally considered a one-time event for that individual. This individual may encounter another exposure of a similar or longer duration in his or her lifetime.

Table J–10 Estimated Dose to Maximally Exposed Individuals Under Incident-Free Transportation Conditions

Receptor	***Dose to Maximally Exposed Individual***
Workers	
Crew member (truck/rail driver)	2 rem per year [a]
Inspector	0.062 rem per event per hour of inspection
Rail yard worker	0.018 rem per event
Public	
Resident (along the rail route)	1.9×10^{-6} rem per event
Resident (along the truck route)	9.3×10^{-7} rem per event
Person in traffic congestion	0.026 rem per event per one-half hour of stop
Resident near the rail yard during classification	2.5×10^{-4} rem per event
Person at a rest stop/gas station	2.4×10^{-4} rem per event per hour of stop
Gas station attendant	7.9×10^{-4} rem per event

[a] Maximum administrative dose limit per year for a trained radiation worker (truck/rail crew member). The value could be higher if drivers are radiation workers operating under a Federal or state-licensed program (49 CFR 173.441).

A member of the public residing along the route would likely receive multiple exposures from passing shipments. The cumulative dose to this resident can be calculated assuming all shipments pass his or her home. The cumulative dose is calculated assuming that the resident is present for every shipment and is unshielded at a distance of 30 meters (about 98 feet) from the route. Therefore, the cumulative dose depends on the number of shipments passing a particular point and is independent of the actual route being considered. If one assumes the maximum resident dose provided in Table J–10 for all waste transport types, then the maximum dose to this resident, if all the materials were to be shipped via this route, would be less than 100 millirem. This dose corresponds to that for truck (or rail) shipments under the Sitewide Removal Alternative, which has an estimated number of shipments of about 104,440 (or 52,220) over about 60 years. This dose translates to less than 2 millirem per year, with a risk of developing a latent fatal cancer of less than 6×10^{-5} over the 60-year duration of transport.

The accident risk assessment and the impacts shown in Tables J–8 and J–9 take into account the entire spectrum of potential accidents, from a fender bender to an extremely severe accident. To provide additional insight into the severity of accidents in terms of the potential dose to an MEI and the public, an accident consequence assessment has been performed for a maximum reasonably foreseeable hypothetical transportation accident with a likelihood of occurrence greater than 1 in 10 million per year. The results, presented in Tables J–8 and J–9, include all conceivable accidents, irrespective of their likelihood.

The following assumptions were used to estimate the consequences of maximum reasonably foreseeable offsite transportation accidents:

- The accident is the most severe with the highest release fraction; high-impact and high-temperature fire accident (highest severity category).
- The individual is 100 meters (330 feet) downwind from a ground release accident.
- The individual is exposed to airborne contamination for 2 hours and ground contamination for 24 hours with no interdiction or cleanup. A stable weather condition (Pasquill Stability Class F) with a wind speed of 1 meter per second (2.2 miles per hour) is considered.
- The population is assumed to be a uniform density within an 80 kilometer (50 mile) radius, and exposed to the entire plume passage and 7 days of ground exposure without interdiction and cleanup. A neutral weather condition (Pasquill Stability Class D) with a wind speed of 4 meters per second (8.8 miles per hour) is considered. As the consequence is proportional to the population density, the accident is assumed to occur in an urban[9] area with the highest density (see Table J–1).
- The number of containers involved in the accident is listed in Table J–2. When multiple Type B or shielded Type A shipping casks are transported in a shipment, a single cask is assumed to have failed in the accident. It is unlikely that a severe accident would breach multiple casks.

Table J–11 provides the estimated dose and risk to an individual and population from a maximum foreseeable truck or rail transportation accident with the highest consequences under each alternative and disposal option. Except for the No Action Alternative and Sitewide Close-In-Place Alternative, the highest consequences for the maximum foreseeable accident are from accidents involving Class B/C waste in a high integrity container in a severe impact in conjunction with a long-duration fire. The consequences are driven by the container structural materials, i.e., a poly-hydrocarbon polymer, which in a fire would lead to high airborne releases. Under the No Action and Sitewide Close-In-Place Alternatives, the highest consequences for the maximum foreseeable accident are those involving Class A wastes in boxes.

[9] *If the likelihood of accident in an urban area is less than 1-in-10 million per year, then the accident is evaluated for a suburban area.*

Table J–11 Estimated Dose to the Population and to Maximally Exposed Individuals Under Most Severe Accident Conditions [a]

Main Disposal Option/ Transport Mode	*Waste Material in the Accident With the Highest Consequences*	*Likelihood of the Accident (per year)*	*Population [b]*		*MEI [c]*	
			Dose (person-rem)	*Risk (LCF)*	*Dose (rem)*	*Risk (LCF)*
Sitewide Removal Alternative						
DOE/Commercial (truck)	Class B and Class C in HIC	1.0×10^{-7}	593	0.356	0.15	9.0×10^{-5}
DOE/Commercial (rail)	Class B and Class C in HIC	3.3×10^{-7}	1,186	0.71	0.30	1.8×10^{-4}
Commercial (truck)	Class B and Class C in HIC	1.3×10^{-7}	593	0.356	0.15	9.0×10^{-5}
Commercial (rail)	Class B and Class C in HIC	4.2×10^{-7}	1,186	0.71	0.30	1.8×10^{-4}
Sitewide Close-In-Place Alternative						
DOE/Commercial (truck) [d]	Class A in Box	3.8×10^{-7}	0.020	1.2×10^{-5}	3.6×10^{-5}	2.2×10^{-8}
DOE/Commercial (rail) [d, e]	Class A in Box	4.2×10^{-8}	0.054	3.2×10^{-5}	7.2×10^{-5}	4.3×10^{-8}
Commercial (truck) [d]	Class A in Box	8.7×10^{-7}	0.020	1.2×10^{-5}	3.6×10^{-5}	2.2×10^{-8}
Commercial (rail) [d, e]	Class A in Box	6.5×10^{-8}	0.054	3.2×10^{-5}	7.2×10^{-5}	4.3×10^{-8}
Phased Decisionmaking Alternative – Phase 1						
DOE/Commercial (truck) [d]	Class B and Class C in Box	1.3×10^{-7}	6.13	0.0037	0.011	6.6×10^{-6}
DOE/Commercial (rail) [d, e]	Class B and Class C in Box	1.4×10^{-8}	16.4	0.0098	0.022	1.3×10^{-5}
Commercial (truck)	Class Band Class C in HIC	1.4×10^{-7}	593	0.356	0.15	9.0×10^{-5}
Commercial (rail)	Class B and Class C in HIC	4.6×10^{-7}	1,186	0.71	0.30	1.8×10^{-4}
No Action Alternative						
DOE/Commercial (truck) [d]	Class A in Box	3.2×10^{-7}	0.020	1.2×10^{-5}	3.6×10^{-5}	2.2×10^{-8}
DOE/Commercial (rail) [d, e]	Class A in Box	3.4×10^{-8}	0.054	3.2×10^{-5}	7.2×10^{-5}	4.3×10^{-8}
Commercial (truck) [d]	Class A in Box	5.8×10^{-7}	0.020	1.2×10^{-5}	3.6×10^{-5}	2.2×10^{-8}
Commercial (rail) [d, e]	Class A in Box	4.3×10^{-8}	0.054	3.2×10^{-5}	7.2×10^{-5}	4.3×10^{-8}

HIC = high-integrity container, LCF = latent cancer fatality, MEI = maximally exposed individual.

[a] The frequencies are based on using a western U.S. disposal site for commercial Class B and Class C wastes. If Barnwell is used, the frequencies would be equal to, or smaller than those given in this table.

[b] Population extends at a uniform density to a radius of 80 kilometers (50 miles). The weather condition was assumed to be Pasquill Stability Class D with a wind speed of 4 meters per second (8.8 miles per hour). Unless otherwise noted, the population doses and risks are presented for an urban area on the transportation route.

[c] The MEI was assumed to be 100 meters (300 feet) downwind from the accident and exposed to the entire plume of the radioactive release. The weather condition was assumed to be Pasquill Stability Class F with a wind speed of 1 meter per second (2.2 miles per hour).

[d] Population dose and risk are for a suburban area along the route. The probability of a maximum foreseeable accident in an urban area along the transportation route is less than 10^{-7} per year.

[e] This accident would have a likelihood of less than 1 in 10 million. It is only provided for completeness.

J.8 Impact of Construction and Operational Material Transport

This section evaluates the impacts of transporting construction/demolition debris and hazardous wastes as well as materials required to construct new facilities, barriers, and erosion controls. The construction materials considered are concrete, cement, sand/gravel/dirt, asphalt, geomembrane fabric, steel, and piping. The impacts were evaluated based on the number of truck shipments required for each of the materials and the distances from their point of origin to the WNYNSC. The origins of these materials were assumed to be at an average distance of 160 kilometers (100 miles) from the site. The truck kilometers for all material shipments under each alternative were calculated by summing all of the activities from construction through closure (where applicable). The truck accident and fatality rates were assumed to be those that were provided earlier for the onsite and local area transports. **Table J–12** summarizes the impacts in terms of total number of kilometers, accidents, and fatalities for all alternatives. The results indicate that there are no large differences in the impacts among all alternatives. Under all alternatives, the expected potential traffic fatalities are very low.

Table J–12 Estimated Impacts of Construction and Operational Material Transport

Alternative	*Total Distance Traveled (kilometers)*	*Number of Accidents*	*Number of Fatalities*
Sitewide Removal	57.8×10^6	19.9	0.7
Sitewide Close-In-Place	95.2×10^6	32.8	1.2
Phased Decisionmaking (Phase 1)	8.2×10^6	2.8	0.1
No Action	0.014×10^6	0.005	0.0002

Note: To convert from kilometers to miles, multiply by 0.6214.

J.9 Conclusions

Based on the results presented in the previous section, the following conclusions have been reached (see Tables J–6 and J–9 through J–11):

- It is unlikely that the transportation of radioactive waste would cause an additional fatality as a result of radiation, either from incident-free operation or postulated transportation accidents.
- The highest risk to the public would be under the Sitewide Removal Alternative, NTS Disposal Site Option, where about 104,440 truck or 52,220 rail shipments of radioactive wastes would be transported to Hanford and other commercial (i.e., EnergySolutions and a western U.S. site) and Government (i.e., assumed, for analysis only, to be WIPP and NTS) disposal sites.
- The lowest risk to the public would be under the Sitewide Close-In-Place Alternative, Commercial Disposal Site Option, where about 1,200 truck or 600 rail shipments of radioactive wastes would be transported to commercial (i.e., EnergySolutions and a western U.S. site) disposal sites.
- The nonradiological accident risks (the potential for fatalities as a direct result of traffic or rail accidents) present the greatest risks. The maximum risks would occur under the Sitewide Removal Alternative using rail shipments. Considering that the transportation activities would occur over a period of time from about 10 to 60 years and that the average number of traffic fatalities in the United States is about 40,000 per year, the traffic fatality risks under all alternatives are very small.

J.10 Long-term Impacts of Transportation

The *Yucca Mountain EIS* (DOE 2002a, 2008) analyzed the cumulative impacts of the transportation of radioactive material, consisting of impacts of historical shipments of radioactive waste and spent nuclear fuel, reasonably foreseeable actions that include transportation of radioactive material, and general radioactive material transportation that is not related to a particular action. The collective dose to the general population and workers was the measure used to quantify cumulative transportation impacts. This measure of impact was chosen because it may be directly related to the LCFs using a cancer risk coefficient. **Table J–13** provides a summary of the total worker and general population collective doses from various transportation activities. The table shows that the impacts of this program are quite small compared with the overall transportation impacts. The total collective worker dose from all types of shipments (historical, the alternatives, reasonably foreseeable actions, and general transportation) was estimated to be about 380,500 person-rem (228 LCFs) for the period 1943 through 2073 (131 years). The total general population collective dose was estimated to be about 349,600 person-rem (210 LCFs). The majority of the collective dose for workers and the general population was due to the general transportation of radioactive material. Examples of these activities are shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of commercial low-level radioactive waste to commercial disposal facilities. The total number of LCFs (among the workers and the general population) estimated to result from radioactive material transportation over the period between 1943 and 2073 is about 440, or an average of about 4 LCFs per year. Over this same period (131 years), approximately 73 million people would die from cancer, based on the National Center for Heath Statistics data. The average annual number of cancer deaths in the United States is about 554,000, with less than 1 percent fluctuation in the number of cancer fatalities in any given year (CDC 2007). The transportation-related LCFs would be 0.0006 percent of the total number of LCFs; therefore, it is indistinguishable from the natural fluctuation in the total annual death rate from cancer.

Table J–13 Cumulative Transportation-related Radiological Collective Doses and Latent Cancer Fatalities (1943 to 2047)

Category	*Collective Worker Dose (person-rem)*	*Collective General Population Dose (person-rem)*
Transportation Impacts in this EIS	2,197 [a]	370 [a]
Other Nuclear Material Shipments		
Historical	330	230
Reasonably Foreseeable Actions	28,000	49,000
General Radioactive Material Transport (1943 to 2073)	350,000	300,000
Total Collective Dose [b] (up to 2073)	380,500	349,600
Total Latent Cancer Fatalities [c]	228	210

[a] Maximum values from Table J–9.
[b] The values are rounded to the nearest hundred.
[c] Total LCFs are calculated assuming 0.0006 LCFs per rem of exposure.
Sources: DOE 2002a, 2008.

J.11 Uncertainty and Conservatism in Estimated Impacts

The sequence of analyses performed to generate the estimates of radiological risk for transportation includes (1) determination of the inventory and characteristics, (2) estimation of shipment requirements, (3) determination of route characteristics, (4) calculation of radiation doses to exposed individuals (including estimation of environmental transport and uptake of radionuclides), and (5) estimation of health effects. Uncertainties are associated with each of these steps. Uncertainties exist in the way that the physical systems being analyzed are represented by the computational models; in the data required to exercise the models (due to measurement errors, sampling errors, natural variability, or unknowns caused simply by the future nature of the actions being analyzed); and in the calculations themselves (e.g., approximate algorithms used by the computers).

In principle, one can estimate the uncertainty associated with each input or computational source and predict the resultant uncertainty in each set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final, or absolute, result; however, conducting such a full-scale quantitative uncertainty analysis is often impractical and sometimes impossible, especially for actions to be initiated at an unspecified time in the future. Instead, the risk analysis is designed to ensure, through uniform and judicious selection of scenarios, models, and input parameters, that relative comparisons of risk among the various alternatives are meaningful. In the transportation risk assessment, this design is accomplished by uniformly applying common input parameters and assumptions to each alternative. Therefore, although considerable uncertainty is inherent in the absolute magnitude of the transportation risk for each alternative, much less uncertainty is associated with the relative differences among the alternatives in a given measure of risk.

In the following sections, areas of uncertainty are discussed for the assessment steps enumerated above. Special emphasis is placed on identifying whether the uncertainties affect relative or absolute measures of risk. The reality and conservatism of the assumptions are addressed. Where practical, the parameters that most significantly affect the risk assessment results are identified.

J.11.1 Uncertainties in Material Inventory and Characterization

The inventories and the physical and radiological characteristics are important input parameters to the transportation risk assessment. The potential number of shipments for all alternatives is primarily based on the projected dimensions of package contents, the strength of the radiation field, the heat that must be dissipated, and assumptions concerning shipment capacities. The physical and radiological characteristics are important in determining the material released during accidents and the subsequent doses to exposed individuals through multiple environmental exposure pathways.

Uncertainties in the inventory and characterization are reflected in the transportation risk results. If the inventory is overestimated (or underestimated), the resulting transportation risk estimates are also overestimated (or underestimated) by roughly the same factor. However, the same inventory estimates are used to analyze the transportation impacts of each of the alternatives. Therefore, for comparative purposes, the observed differences in transportation risks among the alternatives, as given in Tables J–8 and J–9, are believed to represent unbiased, reasonably accurate estimates from current information in terms of relative risk comparisons.

J.11.2 Uncertainties in Containers, Shipment Capacities, and Number of Shipments

The transportation required for each alternative is based in part on assumptions concerning the packaging characteristics and shipment capacities for commercial trucks. Representative shipment capacities have been defined for assessment purposes based on probable future shipment capacities. In reality, the actual shipment capacities may differ from the predicted capacities such that the projected number of shipments and, consequently, the total transportation risk, would change. However, although the predicted transportation risks would increase or decrease accordingly, the relative differences in risks among alternatives would remain about the same.

J.11.3 Uncertainties in Route Determination

Analyzed routes have been determined between all origin and destination sites considered in this EIS. The routes have been determined to be consistent with current guidelines, regulations, and practices, but may not be the actual routes that would be used in the future. In reality, the actual routes could differ from the representative ones with regard to distances and total population along the routes. Moreover, because materials could be transported over an extended time starting at some time in the future, the highway infrastructure and the demographics along routes could change. These effects have not been accounted for in the transportation assessment; however, it is not anticipated that these changes would significantly affect relative comparisons of risk among the alternatives considered in this EIS. Specific routes cannot be identified in advance because the routes are classified to protect national security interests.

J.11.4 Uncertainties in the Calculation of Radiation Doses

The models used to calculate radiation doses from transportation activities introduce a further uncertainty in the risk assessment process. Estimating the accuracy or absolute uncertainty of the risk assessment results is generally difficult. The accuracy of the calculated results is closely related to the limitations of the computational models and to the uncertainties in each of the input parameters that the model requires. The single greatest limitation facing users of RADTRAN, or any computer code of this type, is the scarcity of data for certain input parameters. Populations (off-link and on-link) along the transportation routes, shipment surface dose rates, and individuals residing near the routes are the most uncertain data in dose calculations. In preparing these data, one makes assumptions that the off-link population is uniformly distributed; the on-link population is proportional to the traffic density, with an assumed occupancy of two persons per car; the shipment surface dose rate is the maximum allowed dose rate; and the potential exists for an individual to reside at the edge of the highway. It is clear that not all assumptions are accurate. For example, the off-link population is mostly heterogeneous, and the on-link traffic density varies widely within a geographic zone (i.e., urban, suburban, or rural). Finally, added to this complexity are the assumptions regarding the expected distance between the public and the shipment at a traffic stop, rest stop, or traffic jam and the afforded shielding.

Uncertainties associated with the computational models are reduced by using state-of-the-art computer codes that have undergone extensive review. Because many uncertainties are recognized but difficult to quantify, assumptions are made at each step of the risk assessment process that are intended to produce conservative results (i.e., overestimate the calculated dose and radiological risk). Because parameters and assumptions are applied consistently to all alternatives, this model bias is not expected to affect the meaningfulness of relative comparisons of risk; however, the results may not represent risks in an absolute sense.

J.11.5 Uncertainties in Traffic Fatality Rates

Vehicle accident and fatality rates were taken from data provided in *State-Level Accident Rates for Surface Freight Transportation: A Reexamination*, ANL/ESD/TM-150 (Saricks and Tompkins 1999). Truck and rail accident rates were computed for each state based on statistics compiled by the Federal Highway Administration, Office of Motor Carriers and Federal Railroad Administration, from 1994 to 1996. The rates are provided per unit car-kilometers for each state, as well as national, average and mean values. In this analysis route-specific (origin-destination) rates were used.

The accident statistics in the Saricks and Tompkins report indicate large variations among the state-level accident data. For rail, the state-level fatality rates range between 0.0 to 1.3×10^{-6} with national mean, average, and median values of 7.8×10^{-8}, 2.1×10^{-8}, and 2.3×10^{-8} per car-kilometer, respectively. The route-specific rates, analyzed in this EIS, range between 1.3×10^{-8} and 2.5×10^{-8}. These data show that, depending on the selection of data, mean versus route-specific or median versus route-specific, the fatality rate could vary by, at most, a factor of 3. Recent analysis of rail accident fatality rates for the years 2000 through 2004 indicates a national average value of 1.15×10^{-8} per rail car (DOE 2008). This new value indicates a reduction in fatality rates compared to the average value for the years 1994 through 1996.

For truck, the state-level interstate fatality rates range between 0.0 to 1.7×10^{-8}, with national mean, average, and median values of 8.8×10^{-9}, 9.6×10^{-9}, and 9.2×10^{-9} per car-kilometer, respectively. The route-specific rates, analyzed in this EIS, range between 8.0×10^{-9} and 1.6×10^{-8}. These data show that route-specific rates are within the range of the state-level, and the same order of magnitude as that of the national, mean values.

Finally, it should be emphasized that the analysis was based on accident data for the years 1994 through 1996. While these data may be the best available data, subsequent and future accident and fatality rates may change as a result of vehicle and highway improvements. The recent DOT national accident and fatality statistics for large trucks and buses indicate lower accident and fatality rates for recent years as compared to those of 1994 through 1996 and earlier statistics data (DOT 2009).

J.12 References

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