Appendix G

Transportation

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G. TRANSPORTATION

This appendix to 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* (DOE/EIS-0250F-S1) (Repository SEIS) summarizes the methods and data the U.S. Department of Energy (DOE or the Department) used to estimate the potential transportation impacts to workers and the public from shipments of spent nuclear fuel and high-level radioactive waste to the proposed repository. This appendix summarizes, incorporates by reference, and updates the analyses in Appendix J of 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* (DOE/EIS-0250F; DIRS 155970-DOE 2002, pp. J-1 to J-199) (Yucca Mountain FEIS).

Section G.1 discusses the methods and data used to estimate impacts at generator sites from loading activities. Section G.2 presents the representative transportation routes DOE would use to ship spent nuclear fuel and high-level radioactive waste from those sites to the proposed repository, Section G.3 lists the numbers of shipments from each site, and Section G.4 describes the radionuclide inventories the analysis used for estimation of impacts. Section G.5 describes the methods and data used to estimate the impacts for incident-free transportation, and Sections G.6 and G.7 describe the methods and data used to estimate transportation accident risks and the consequences of severe transportation accidents, respectively. Section G.8 describes the methods and data used to estimate the consequences of potential sabotage events in relation to transportation. Section G.9 discusses general topics DOE examined for this analysis. Section G.10 contains figures of the representative transporation routes for each state through which shipments would pass, and lists the impacts of those shipments in those states. Section G.11 provides data used to estimate the impacts from the transport of other materials and personnel to the repository.

G.1 Impacts at Generator Sites

This section describes the methods and data used to estimate the impacts from loading activities at generator sites. For rail shipments of commercial spent nuclear fuel from the generator sites, loading operations would include placement of the spent nuclear fuel into a transportation, aging, and disposal (TAD) canister, placement of the TAD canister into a rail transportation cask, and placement of the transportation cask on a railcar or heavy-haul truck. For truck shipments of commercial spent nuclear fuel, uncanistered spent nuclear fuel would be placed in a truck transportation cask, and the truck cask would be placed on a truck trailer.

DOE would load its spent nuclear fuel into disposable canisters at three DOE sites and high-level radioactive waste into disposable canisters at four DOE sites. Loading operations would consist of placing the canisters into a rail transportation cask and placing the transportation cask on a railcar. A small amount of uncanistered spent nuclear fuel would be loaded into truck casks at the DOE sites.

G.1.1 IMPACTS OF SHIPPING CANISTERS AND CAMPAIGN KITS TO GENERATOR SITES

DOE would operate the proposed repository using a primarily canistered approach in which most commercial spent nuclear fuel would be packaged at the generator sites into TAD canisters. This would require shipment of empty TAD canisters to the commercial generator sites. These shipments of empty canisters would be by truck. Before the loading of a truck or rail transportation cask, equipment used in the handling and loading of the cask, known as a campaign kit, would be shipped to the generator sites. These shipments also would be by truck.

The shipments of empty TAD canisters would not be radioactive material shipments, so there would be no radiation dose to the public or to workers. The campaign kits could become contaminated during use, but would be decontaminated before shipping. Therefore, the radiation dose and radiological risks associated with shipping campaign kits would be negligible. The impacts of transporting canisters and campaign kits would be from fatalities from exposure to vehicle emissions and traffic fatalities. Injuries were not estimated because they are not readily combined with radiological impacts, which were quantified in terms of latent cancer fatalities. DOE estimated these impacts based on a 6,000-kilometer (3,700-mile) round-trip shipping distance for the canisters and the campaign kits and a population density of 220 people per square kilometer (570 people per square mile). The Department used data from the 2000 Census extrapolated to 2067 to estimate the population density along the representative truck routes (see Section G.2).

Table G-1 summarizes the data DOE used to estimate the impacts of these shipments.

Table G-1. Data used to estimate impacts from shipping canisters and campaign kits.

Quantity	Value	Reference
Number of canisters shipped	6,499[a]	DIRS 181377-BSC 2007, Section 7
Number of campaign kits shipped	4,942	DIRS 181377-BSC 2007, Section 7
Vehicle emission fatality rate	1.5×10^{-11} fatalities/km per person/km^{2}[b,c]	DIRS 157144-Jason Technologies 2001, p. 98
Traffic fatality rate	1.71×10^{-8} fatalities/km[b]	DIRS 182082-FMCSA 2007, Table 13

Notes: Vehicle emission fatality rate and traffic fatality rate are for trucks.

a. About an additional 1,000 empty TAD canisters would be shipped directly to the repository to package commercial spent nuclear fuel that could not be shipped from the generator sites using rail casks.

b. To convert kilometers to miles, multiply by 0.62137.

c. To convert square kilometers to square miles, multiply by 0.3861.

km = kilometer.

G.1.2 RADIOLOGICAL IMPACTS TO WORKERS FROM LOADING

At commercial generator sites, impacts to involved workers would result from loading spent nuclear fuel into canisters, loading canisters into rail transportation casks, and, at some sites, loading spent nuclear fuel into truck casks. For DOE spent nuclear fuel and high-level radioactive waste, impacts would result from loading canisters into rail transportation casks and a small amount of uncanistered spent nuclear fuel into truck casks. Noninvolved workers would not be in proximity to the canisters or casks and would not be exposed during loading. Therefore, DOE did not estimate radiological impacts for these noninvolved workers. Table G-2 summarizes the data DOE used to estimate the radiological impacts from these activities.

A TAD canister is similar to a dry storage canister in appearance, capacity, and the operational procedures that would be in use for loading. Therefore, for the loading of spent nuclear fuel into TAD canisters at commercial generator sites, DOE based radiation doses on utility data compiled by the U.S. Nuclear Regulatory Commission (NRC) for loading 87 dry storage canisters at four commercial sites (DIRS 181757-NRC 2002, Attachment 3; DIRS 181758-Spitzberg 2004, Attachment 2; DIRS 181759-Spitzberg 2005, Attachment 2; DIRS 181760-Spitzberg 2005, Attachment 2). Using the utility data, DOE estimated the average radiation dose for loading spent nuclear fuel into canisters to be 0.400 person-rem per

Table G-2. Data used to estimate radiation doses to workers for loading.

Operation	Radiation dose	Number of canisters or casks for operation	Reference
Rail cask			
Load commercial spent nuclear fuel into canister	0.400 person-rem per canister	6,499 canisters[a]	Average of utility data in DIRS 181757-NRC 2002, Attachment 3; DIRS 181758-Spitzberg 2004, Attachment 2; DIRS 181759-Spitzberg 2005, Attachment 2; DIRS 181760-Spitzberg 2005, Attachment 2
Transfer canister from storage, load into rail cask, load rail cask onto railcar	0.663 person-rem per cask	9,495 casks[b,c]	Steps 12 and 13 in DIRS 104794-CRWMS M&O 1994, p. A-28
Truck cask			
Load uncanistered spent nuclear fuel into truck cask, load truck cask onto truck trailer	0.432 person-rem per cask	2,650 casks[d]	Steps 1, 2, 3a, 4a, and 5a in DIRS 104794-CRWMS M&O 1994, pp. A-9 to A-11

a. Includes only TAD canisters (DIRS 181377-BSC 2007, Section 7).
b. Includes commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste (DIRS 181377-BSC 2007, Section 7).
c. 6,499 casks of commercial spent nuclear fuel containing TAD canisters, 307 casks of commercial spent nuclear fuel containing dual-purpose canisters, 1,924 casks of high-level radioactive waste, and 765 casks of DOE spent nuclear fuel.
d. DIRS 181377-BSC 2007, Section 7.

DOE = U.S. Department of Energy.
TAD = Transportation, aging, and disposal (canister).

canister. For comparison, the estimated radiation dose for these same activities would be 1.992 person-rem based on using calculated data (DIRS 104794-CRWMS M&O 1994, p. A-24).

DOE used data from *Health and Safety Impacts Analysis for the Multi-Purpose Canister System and Alternatives* (DIRS 104794-CRWMS M&O 1994, pp. A-9 and A-24) to estimate radiation doses for the loading of (1) canisters containing spent nuclear fuel into rail casks and uncanistered spent nuclear fuel into truck casks, (2) canisters containing high-level radioactive waste and canisters containing DOE spent nuclear fuel into rail casks, and (3) rail casks onto railcars and truck casks onto truck trailers. For loading uncanistered spent nuclear fuel into truck casks and loading the truck casks onto trailers, the estimated radiation dose would be 0.432 person-rem per cask (DIRS 104794-CRWMS M&O 1994, p. A-9). For loading canisters into rail casks and loading the rail casks onto railcars, the estimated radiation dose would be 0.663 person-rem per cask (DIRS 104794-CRWMS M&O 1994, p. A-24).

G.1.3 INDUSTRIAL SAFETY IMPACTS TO WORKERS FROM LOADING

DOE based the analysis of industrial safety impacts on an average loading duration of 2.3 days per rail cask for pressurized-water-reactor spent nuclear fuel and 2.5 days per rail cask for boiling-water-reactor spent nuclear fuel (DIRS 155970-DOE 2002, p. J-34). For truck casks, DOE based the analysis on an average loading duration of 1.3 days per cask for pressurized-water-reactor spent nuclear fuel and 1.4 days per cask for boiling-water-reactor spent nuclear fuel (DIRS 155970-DOE 2002, p. J-34). The Department based loading durations for DOE spent nuclear fuel and high-level radioactive waste on the loading durations for pressurized-water-reactor spent nuclear fuel. It based the industrial safety impacts on a crew size of 13 (DIRS 155970-DOE 2002, p. J-34) dedicated solely to performing cask-handling work and an 8-hour working day. Based on these data, 1,347 worker-years would be spent during loading activities for involved workers. Using the assumption that the noninvolved workforce would be 25 percent of the involved workforce, DOE determined that noninvolved workers would spend 337 worker-years during loading activities (DIRS 155970-DOE 2002, p. 6-38).

DOE based incidence and fatality rates for involved workers on Bureau of Labor Statistics data for 2005 (DIRS 179131-BLS 2006, all; DIRS 179129-BLS 2007, all). Bureau of Labor Statistics data are organized into industries. DOE used data for workers in the transportation and warehousing industries to estimate impacts because they closely represent the hazards associated with loading casks. Data from DOE sources were not used because most of the generator sites were associated with private industry rather than DOE. For noninvolved workers, the Department based the rates on the professional and business services industries.

For vehicle emission fatalities, DOE based the analysis of industrial safety impacts on a vehicle emission fatality rate of 9.4×10^{-12} fatalities per kilometer per persons per square kilometer (DIRS 157144-Jason Technologies 2001, p. 99) and on a population density of 6 persons per square kilometer (16 persons per square mile), which is representative of a rural area (DIRS 101892-NRC 1977, p. E-2). For traffic fatalities, DOE based the analysis of industrial safety impacts on a fatality rate of 1.0×10^{-8} fatalities per kilometer (DIRS 182082-FMCSA 2007, Table 2) over the period from 2001 through 2005. DOE also based the analysis on workers driving 37 kilometers (23 miles) round trip for 251 days per year. Table G-3 summarizes the data DOE used to estimate the industrial safety impacts from loading activities.

Table G-3. Data used to estimate industrial safety impacts to workers for loading.

Quantity	Value	Reference
Involved workers		
Worker-years	1,347[a]	Calculated
Total recordable cases rate	0.082 per worker-year	DIRS 179131-BLS 2006, all; for warehousing and storage industries
Lost workday cases rate	0.054 per worker-year	DIRS 179131-BLS 2006, all; for warehousing and storage industries
Fatality rate	1.76×10^{-4} per worker-year	DIRS 179129-BLS 2007, all; for transportation and warehousing industries
Noninvolved workers		
Worker-years	337	Calculated
Total recordable cases rate	0.024 per worker-year	DIRS 179131-BLS 2006, all; for professional and business services, management of companies and enterprises
Lost workday cases rate	0.012 per worker-year	DIRS 179131-BLS 2006, all; for professional and business services, management of companies and enterprises
Fatality rate	3.5×10^{-5} per worker-year	DIRS 179129-BLS 2007, all; for professional and business services
Involved and noninvolved workers		
Vehicle emission fatality rate	9.4×10^{-12} fatalities/km per person/km^{2}[(b,c)]	DIRS 157144-Jason Technologies 2001, p. 99
Traffic fatality rate	1.0×10^{-8} fatalities per km[b]	DIRS 182082-FMCSA 2007, Table 2

Notes: Vehicle emission fatality rate and traffic fatality rate are for automobiles.

a. Based on loading 6,736 pressurized-water-reactor spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste rail casks; 1,940 pressurized-water-reactor truck casks; 2,759 boiling-water-reactor rail casks; and 710 boiling-water reactor truck casks.

b. To convert kilometers to miles, multiply by 0.62137.

c. To convert square kilometers to square miles, multiply by 0.3861.

km = kilometer.

G.2 Transportation Routes

At this time, before receipt of a construction authorization for the proposed repository and years before a possible first shipment, the specific rail and highway routes shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain will use have not been identified. Consequently, the analysis of impacts presented in this Repository SEIS is based on routes that could be used and that DOE believes are representative of those that will be used. Therefore, the highway and rail routes that DOE used for analysis in this SEIS are called representative routes.

DOE used the TRAGIS computer program (DIRS 181276-Johnson and Michelhaugh 2003, all) to identify the representative rail and truck routes used in the analysis. TRAGIS is a Web-based geographic information system transportation routing computer code. The TRAGIS rail network is developed from a 1-to-100,000-scale rail network derived from the United States Geological Survey digital line graphs. This network currently represents more than 240,000 kilometers (150,000 miles) of rail lines in the continental United States and has over 28,000 segments (links) and over 4,000 intersections (nodes). All rail lines with the exception of industrial spurs are included. The rail network includes nodes for nuclear reactor sites, DOE sites, and military bases that have rail access. The rail network has been extensively modified and is revised on a regular schedule to reflect rail line abandonment, company mergers, short line spin-offs, and new rail construction.

To calculate rail routes, the TRAGIS computer program uses rules that are designed to simulate routing practices that have been historically used by railroad companies in moving regular freight and dedicated trains in the United States. The basic rule used to calculate rail routes causes the program to attempt to identify the shortest route from an origin to a destination. Another rule used in the program biases the lengths of route segments that have the highest density of rail traffic to make these segments appear, for purposes of calculation, to be shorter. The effect of the bias is to prioritize selection of routes that use railroad main lines, which have the highest traffic density. As a general rule, routing along the high traffic lines replicates railroad operational practices. A third rule constrains the program to select routes used by an individual railroad company to lines the company owns or over which has permission to operate. This rule ensures the number of interchanges between railroads that the TRAGIS computer program calculates for a route is correct. The number of interchanges between railroads is a significant consideration when determining a realistic and representative route.

Another rule used in the TRAGIS computer program to calculate a rail route determines the sequence of different railroad companies whose rail lines would be linked to form the route. Because a delay and additional operations are involved in transferring a shipment (interchanging) from one railroad to another, in order to provide efficient service, railroads typically route shipments to minimize the number of interchanges that occur. Reducing the number of interchanges also tends to reduce the time a shipment is in transit. This practice is simulated in the TRAGIS computer program by imposing a penalty for each interchange that is identified for a route. The interchange penalties cause the TRAGIS computer program to increase the calculated length of routes when more than one railroad company’s lines are linked. As a consequence, the algorithm used in the TRAGIS computer program to identify routes that have the least apparent length gives advantage to routes that also have the fewest interchanges between railroads and the fewest involved railroad companies.

Last, a rule in the TRAGIS computer program is designed to simulate the commercial behavior of railroad companies to maximize their portion of revenues from shipments. The effect of this behavior is that routing is often affected by originating railroads, who control the selection of routes on their lines to realize as much of a shipment's revenue as possible. The result is that originating railroads transport shipments as far as possible (in the direction of the destination) on their systems before interchanging the shipments with other railroads. This behavior is simulated in the TRAGIS computer program by imposing a bias on the length of the originating railroad's lines to give the railroad an advantage when calculating a route. In evaluating the length of the route, the model treats 1 mile of travel on the originating railroad as being "less" than 1 mile on other railroads.

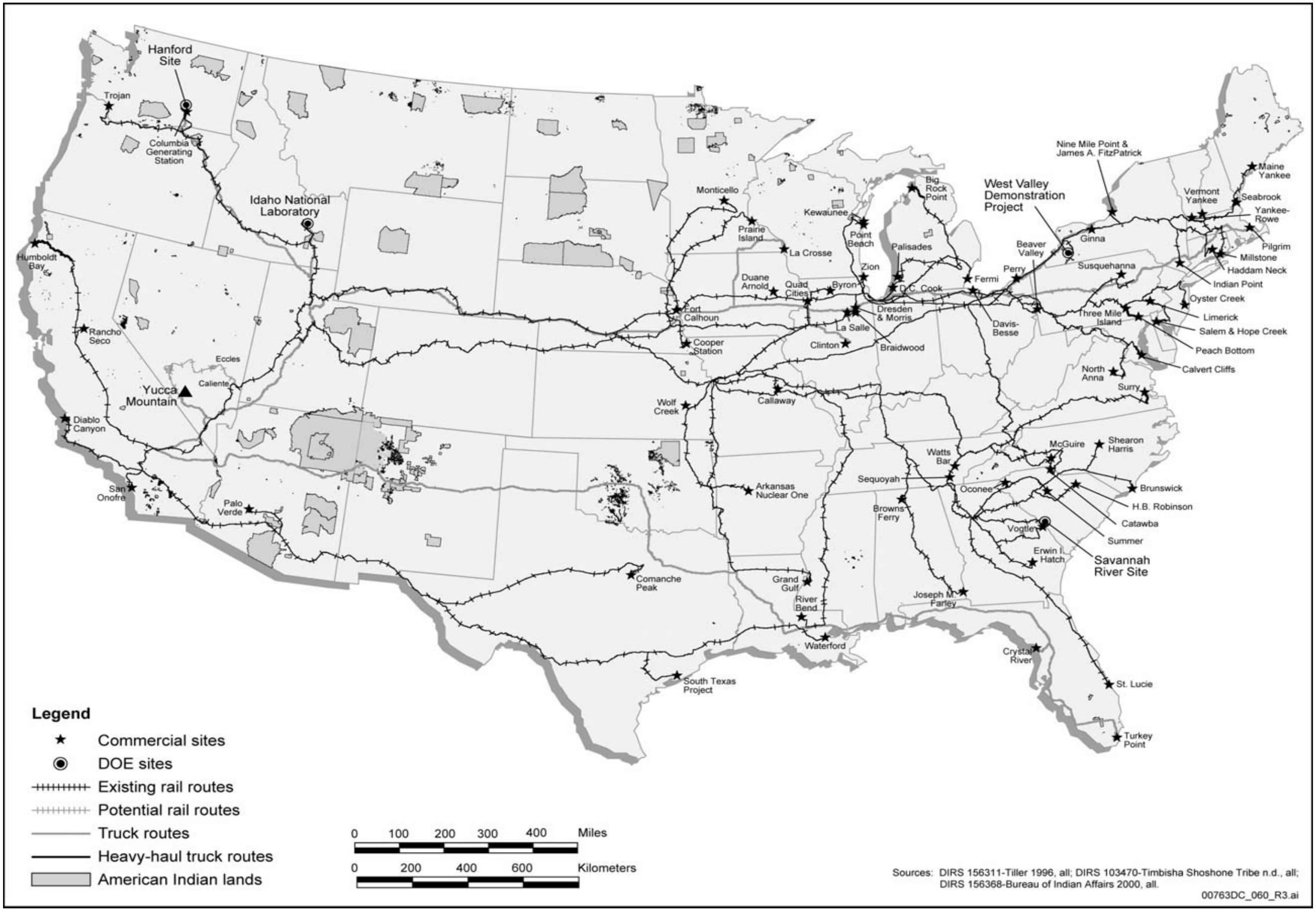
The TRAGIS highway network is developed from a 1-to-100,000-scale road network derived from United States Geological Survey digital line graphs and Bureau of the Census TIGER data. The network represents slightly more than 378,000 kilometers (235,000 miles) of roadways and includes all Interstate Highways, most U.S. Highways except those that closely parallel Interstate Highways, major state highways, and other local roads that connect to various specific sites of interest. The network currently includes over 22,000 highway segments (links) and over 16,000 intersections (nodes). The network includes nuclear reactor sites, DOE sites, and commercial and military airports.

TRAGIS provides a variety of routing rules that can be used to calculate highway routes. The default rules yield highway routes that commercial motor carriers of freight would be expected to use. In addition, TRAGIS can be used to (1) determine routes that meet the U.S. Department of Transportation regulations for shipments of Highway Route-Controlled Quantities of Radioactive Material; (2) identify the shortest route between an origin and destination; or (3) identify the route that could be expected to result in the least total time in transit.

The population data in TRAGIS are derived from the LandScan USA 15-arc second (approximately 360-by-460-meter) grid cell population database. This national database represents the nighttime population distribution and is developed from a combination of data sources including 2000 Bureau of the Census block group population, roads from the Bureau of the Census TIGER data, slope from the National Imagery and Mapping Agency's Digital Terrain Elevation Data, and land cover from the United States Geological Survey National Land Cover Database. The data are modeled to best approximate the actual location of the resident population. Because of the proximity of the repository to Las Vegas, the resident population in Las Vegas was modified to include casino guests and casino workers, based on data from the Nevada Agency for Nuclear Projects (DIRS 158452-Nevada Agency for Nuclear Projects 2002, Table 3.8.12).

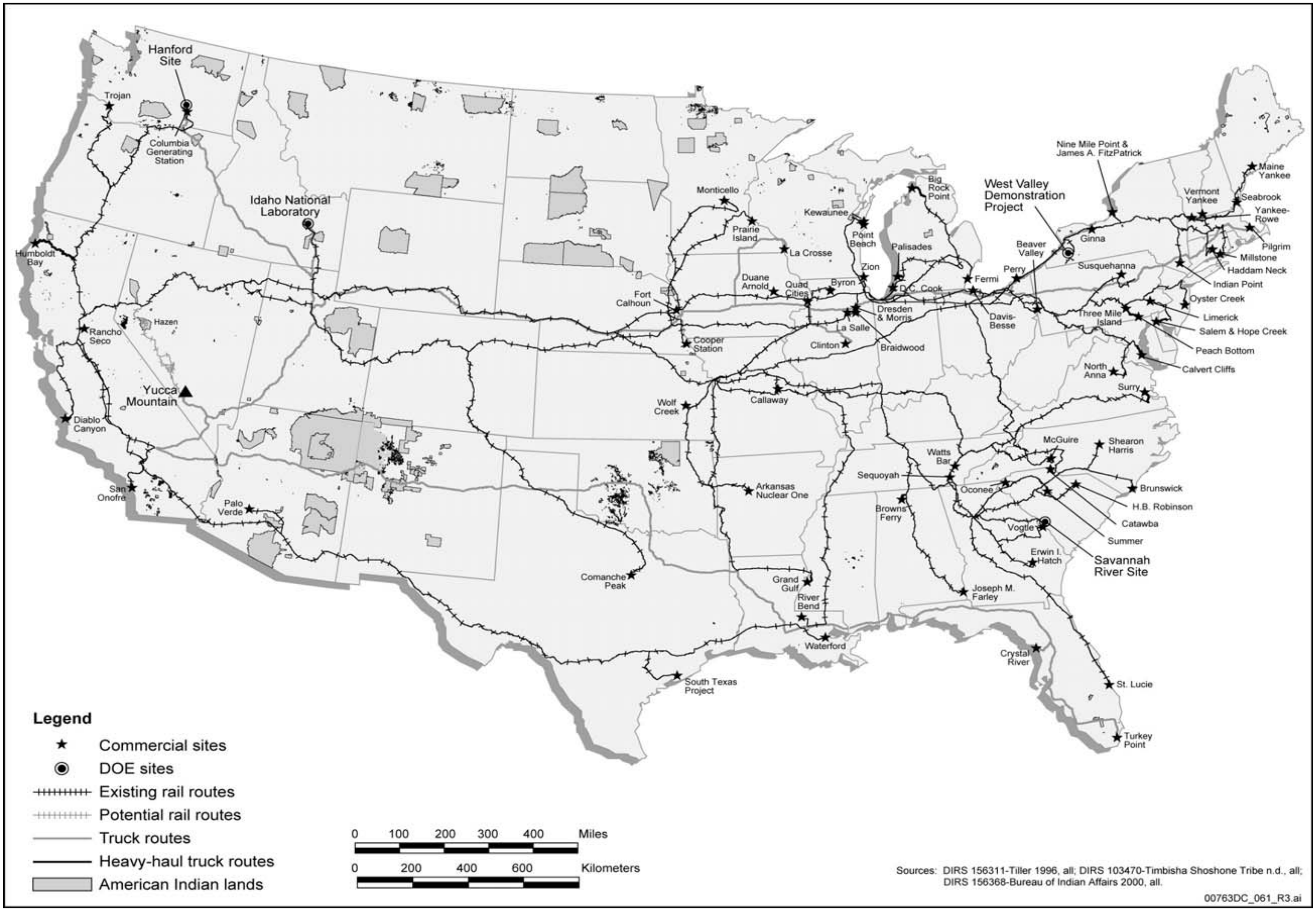
The routes used in the analysis that are also representative of routes that could be used for shipments to the repository are illustrated in Figures G-1 and G-2. DOE determined rail routes in two steps. In the first step, representative routes were determined from the generator sites to either Caliente or Hazen, Nevada. In the second step, the rail alternative segments that comprise the rail alignment with the highest population in the Caliente or Mina rail alignment were used to determine the representative route from Caliente or Hazen to the repository. Tables G-4 and G-5 list the distances from the generator sites to Caliente and Hazen. Table G-6 lists the distances from Caliente and Hazen to the repository.

Some generator sites do not have direct rail access. For these sites, heavy-haul trucks would have to be used to move the rail cask containing spent nuclear fuel to a nearby railhead. Barges could also be used;



Sources: DIRS 156311-Tiller 1996, all; DIRS 103470-Timbisha Shoshone Tribe n.d., all; DIRS 156368-Bureau of Indian Affairs 2000, all.

Figure G-1. Representative rail and truck transportation routes if DOE selected the Caliente rail corridor in Nevada.



Sources: DIRS 156311-Tiller 1996, all; DIRS 103470-Timbisha Shoshone Tribe n.d., all; DIRS 156368-Bureau of Indian Affairs 2000, all.

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Figure G-2. Representative rail and truck transportation routes if DOE selected the Mina rail corridor in Nevada.

Table G-4. Distances for representative rail routes from generator sites to Caliente, Nevada.

Origin	Origin state	Rural kilometers[a]	Suburban kilometers[a]	Urban kilometers[a]
Browns Ferry	AL	2,947.0	490.2	97.9
Farley	AL	3,331.8	643.9	109.6
Arkansas	AR	2,668.0	305.9	51.0
Palo Verde	AZ	1,216.5	197.8	63.7
Diablo Canyon	CA	781.9	166.2	131.0
Humboldt Bay	CA	1,020.2	289.4	110.1
Rancho Seco	CA	853.7	213.0	82.4
San Onofre	CA	584.1	107.1	77.1
Haddam Neck	CT	3,369.2	905.6	216.2
Millstone	CT	3,417.4	942.7	218.3
St. Lucie	FL	3,642.7	940.1	166.0
Hatch	GA	3,459.9	724.0	105.4
Vogtle	GA	3,504.7	723.5	104.5
Arnold	IA	2,240.8	288.1	46.6
Idaho National Laboratory	ID	796.1	93.4	25.7
Braidwood	IL	2,657.4	402.6	96.8
Byron	IL	2,428.5	321.3	47.4
Dresden	IL	2,479.0	367.5	62.4
LaSalle	IL	2,525.7	275.8	40.4
Morris	IL	2,478.9	367.4	62.4
Quad Cities	IL	2,456.3	283.7	42.0
Zion	IL	2,467.3	387.7	86.3
Wolf Creek	KS	2,242.7	218.5	46.9
River Bend	LA	3,288.1	584.7	106.6
Waterford	LA	3,060.6	505.1	122.6
Yankee Rowe	MA	3,284.5	797.3	190.8
Calvert Cliffs	MD	3,267.0	709.0	223.4
Maine Yankee	ME	3,484.0	991.0	235.6
Big Rock Point	MI	2,913.0	666.9	154.7
Fermi	MI	2,742.3	542.6	158.5
Palisades	MI	2,543.4	434.2	119.6
Monticello	MN	2,477.4	331.4	51.6
Prairie Island	MN	2,373.0	325.0	48.0
Callaway	MO	2,346.5	243.6	52.2
Grand Gulf	MS	3,052.8	420.7	60.1
Brunswick	NC	3,529.1	877.4	142.6
Harris	NC	3,450.6	867.4	142.3

Table G-4. Distances for representative rail routes from generator sites to Caliente, Nevada (continued).

Origin	Origin state	Rural kilometers[a]	Suburban kilometers[a]	Urban kilometers[a]
McGuire	NC	3,450.8	730.1	155.3
Cooper	NE	2,009.6	218.4	47.6
Fort Calhoun	NE	1,923.9	179.6	38.4
Seabrook	NH	3,420.0	930.0	221.5
Hope Creek	NJ	3,131.0	911.4	315.0
Oyster Creek	NJ	3,180.8	922.9	326.0
Salem	NJ	3,131.0	911.4	315.0
FitzPatrick	NY	3,138.8	698.0	192.5
Indian Point	NY	3,360.0	792.9	204.9
Nine Mile Point	NY	3,138.5	697.4	192.5
West Valley	NY	3,028.7	628.8	167.4
Davis-Besse	OH	2,695.9	485.2	143.6
Perry	OH	3,099.3	412.9	115.2
Trojan	OR	1,763.2	246.2	72.6
Beaver Valley	PA	3,170.2	463.7	110.6
Limerick	PA	3,430.7	681.5	195.3
Peach Bottom	PA	3,416.4	639.0	171.5
Susquehanna	PA	3,155.2	799.5	244.3
Three Mile Island	PA	3,398.9	633.0	171.9
Catawba	SC	3,339.1	784.0	113.3
Oconee	SC	3,275.2	734.1	112.1
Robinson	SC	3,334.6	839.8	147.6
Savannah River Site	SC	3,308.8	726.8	149.8
Summer	SC	3,385.4	839.9	119.8
Sequoyah	TN	3,086.3	526.1	85.3
Watts Bar	TN	3,057.4	502.6	84.7
Comanche Peak	TX	2,456.5	379.8	87.0
South Texas	TX	2,769.1	336.3	93.2
North Anna	VA	3,379.6	732.3	227.4
Surry	VA	3,552.7	812.2	111.0
Vermont Yankee	VT	3,390.0	881.3	201.3
Columbia	WA	1,540.6	176.9	40.0
Hanford Site	WA	1,575.1	177.0	40.0
Kewaunee	WI	2,619.9	490.8	125.8
Point Beach	WI	2,619.9	490.8	125.8

Notes: Urban areas have a population density greater than 1,284 people per square kilometer (3,326 people per square mile). Rural areas have a population density less than 54 people per square kilometer (139 people per square mile). Suburban areas have a population density between 54 and 1,284 people per square kilometer.

a. To convert kilometers to miles, multiply by 0.62137.

Table G-5. Distances for representative rail routes from generator sites to Hazen, Nevada.

Origin	Origin state	Rural kilometers[a]	Suburban kilometers[a]	Urban kilometers[a]
Browns Ferry	AL	3,200.6	470.3	83.2
Farley	AL	3,585.5	624.0	94.9
Arkansas	AR	2,921.6	286.0	36.3
Palo Verde	AZ	1,250.5	459.6	172.3
Diablo Canyon	CA	512.5	233.7	103.5
Humboldt Bay	CA	359.8	140.5	32.7
Rancho Seco	CA	241.3	93.8	40.0
San Onofre	CA	774.1	306.1	161.5
Haddam Neck	CT	3,622.8	885.8	201.5
Millstone	CT	3,671.0	922.8	203.6
St. Lucie	FL	3,896.3	920.3	151.3
Hatch	GA	3,713.5	704.1	90.7
Vogtle	GA	3,758.3	703.6	89.8
Arnold	IA	2,494.4	268.3	31.9
Idaho National Laboratory	ID	1,049.1	69.6	10.3
Braidwood	IL	2,911.0	382.8	82.1
Byron	IL	2,682.1	301.4	32.7
Dresden	IL	2,732.6	347.6	47.7
LaSalle	IL	2,907.3	332.5	55.3
Morris	IL	2,732.5	347.5	47.7
Quad Cities	IL	2,837.9	340.4	56.9
Zion	IL	2,720.9	367.8	71.6
Wolf Creek	KS	2,496.3	198.6	32.2
River Bend	LA	3,541.7	564.8	91.9
Waterford	LA	3,094.7	766.9	231.2
Yankee Rowe	MA	3,538.1	777.5	176.1
Calvert Cliffs	MD	3,520.6	689.1	208.7
Maine Yankee	ME	3,737.6	971.1	220.9
Big Rock Point	MI	3,166.6	647.0	139.9
Fermi	MI	2,995.9	522.8	143.7
Palisades	MI	2,797.0	414.4	104.9
Monticello	MN	2,859.0	388.1	66.5
Prairie Island	MN	2,626.6	305.2	33.2
Callaway	MO	2,600.1	223.7	37.5
Grand Gulf	MS	3,306.5	400.8	45.4
Brunswick	NC	3,782.7	857.6	127.9
Harris	NC	3,704.2	847.6	127.6

Table G-5. Distances for representative rail routes from generator sites to Hazen, Nevada (continued).

Origin	Origin state	Rural kilometers[a]	Suburban kilometers[a]	Urban kilometers[a]
McGuire	NC	3,704.4	710.2	140.6
Cooper	NE	2,263.3	198.6	32.9
Fort Calhoun	NE	2,177.5	159.8	23.7
Seabrook	NH	3,673.6	910.2	206.8
Hope Creek	NJ	3,384.6	891.5	300.3
Oyster Creek	NJ	3,434.4	903.0	311.3
Salem	NJ	,3384.6	891.5	300.3
FitzPatrick	NY	3,392.4	678.1	177.8
Indian Point	NY	3,613.6	773.0	190.2
Nine Mile Point	NY	3,392.1	677.5	177.8
West Valley	NY	3,282.3	608.9	152.7
Davis-Besse	OH	2,949.5	465.4	128.9
Perry	OH	3,352.9	393.1	100.5
Trojan	OR	1,013.2	335.4	90.9
Beaver Valley	PA	3,423.8	443.8	95.9
Limerick	PA	3,684.3	661.6	180.6
Peach Bottom	PA	3,670.0	619.2	156.8
Susquehanna	PA	3,408.9	779.6	229.6
Three Mile Island	PA	3,652.5	613.1	157.2
Catawba	SC	3,592.7	764.2	98.6
Oconee	SC	3,528.8	714.3	97.4
Robinson	SC	3,588.2	819.9	132.9
Savannah River Site	SC	3,562.4	707.0	135.1
Summer	SC	3,639.0	820.1	105.1
Sequoyah	TN	3,339.9	506.2	70.6
Watts Bar	TN	3,311.0	482.8	70.0
Comanche Peak	TX	2,731.9	340.4	65.5
South Texas	TX	2,803.2	598.0	201.9
North Anna	VA	3,633.2	712.5	212.7
Surry	VA	3,806.3	792.4	96.3
Vermont Yankee	VT	3,643.6	861.4	186.6
Columbia	WA	1,225.3	248.4	45.3
Hanford Site	WA	1,259.9	248.5	45.3
Kewaunee	WI	2,873.5	470.9	111.1
Point Beach	WI	2,873.5	470.9	111.1

Notes: Urban areas have a population density greater than 1,284 people per square kilometer (3,326 people per square mile). Rural areas have a population density less than 54 people per square kilometer (139 people per square mile). Suburban areas have a population density between 54 and 1,284 people per square kilometer.

a. To convert kilometers to miles, multiply by 0.62137

Table G-6. Distances for representative rail routes from Caliente and Hazen to the repository.

Origin	County	Rural kilometers[a]	Suburban kilometers	Urban kilometers
Caliente				
	Lincoln	148.75	0.35	0
	Nye	358.64	0	0
	Esmeralda	31.08	0.12	0
Hazen				
	Churchill	18.61	0	0
	Lyon	89.09	0.88	0
	Mineral	154.81	0	0
	Esmeralda	132.76	0.11	0
	Nye	149.55	0	0

Notes: Urban areas have a population density greater than 1,284 people per square kilometer (3,326 people per square mile). Rural areas have a population density less than 54 people per square kilometer (139 people per square mile). Suburban areas have a population density between 54 and 1,284 people per square kilometer.

a. To convert kilometers to miles, multiply by 0.62137.

Section G.9.10 discusses barge shipments. Table G-7 lists the distances from these generator sites to the nearby railheads.

Some generator sites do not have the ability to handle a rail cask at their facilities. Unless site capabilities are upgraded at these sites, truck casks would have to be used to ship the spent nuclear fuel. In addition, there would be a small number of commercial spent nuclear fuel truck shipments from the Hanford Site and the Idaho National Laboratory. For truck shipments, DOE determined the representative routes based on the U.S. Department of Transportation rules for Highway Route-Controlled Quantity shipments in 49 CFR 397.101. Figures G-1 and G-2 show the representative truck routes used in the analysis from these generator sites to the repository and Table G-8 lists the distances from these generator sites to the repository.

The population density data DOE used in this Repository SEIS from TRAGIS and for the Caliente and Mina rail alignments were for 800 meters (0.5 mile) on either side of the representative rail or truck route and were based on 2000 Census data. Because the analysis considered that the repository would operate for 50 years, DOE used Bureau of the Census population estimates for 2000 through 2030 to extrapolate population densities along the routes to 2067. DOE used population estimates for 2026 through 2030 to extrapolate population densities for 2031 through 2067. In Nevada, DOE used the *Regional Economic Model, Inc.* (REMI) computer model and data from the Nevada State Demographer to extrapolate population densities. Table G-9 lists the population escalation factors. DOE estimated 2067 population within this 1,600-meter (1 mile) band by multiplying by the appropriate state population escalation factor.

G.3 Shipments

The Yucca Mountain FEIS (DIRS 155970-DOE 2002, Tables J-5, J-6, and J-7) analyzed the shipment of 9,646 rail casks and 1,079 truck casks of spent nuclear fuel and high-level radioactive waste to the repository. Since the completion of the Yucca Mountain FEIS in 2002, DOE has updated the number of rail and truck casks to be shipped to the repository through additional data collection and analysis. In addition, the Department has developed updated estimates of shipments that incorporate the use of TAD canisters and updated cask handling assumptions at each reactor site. Table G-10 summarizes the number

Table G-7. Distances for representative heavy-haul truck routes from generator sites to nearby railroads.

Origin	Origin state	Rural kilometers[a]	Suburban kilometers[a]	Urban kilometers[a]
Browns Ferry[b]	AL	19.4	8.4	0.4
Diablo Canyon[b]	CA	22.3	7.0	2.6
Humboldt Bay[b]	CA	206.8	28.5	6.1
Haddam Neck[b]	CT	10.2	9.6	1.0
St. Lucie[b]	FL	13.0	7.5	0.6
Yankee Rowe	MA	25.9	7.0	1.3
Calvert Cliffs[b]	MD	25.4	31.5	0.3
Big Rock Point	MI	60.5	12.0	0.8
Palisades[b]	MI	15.9	13.9	0.1
Callaway	MO	19.1	1.9	0.6
Grand Gulf[b]	MS	32.6	2.2	0.0
Cooper[b]	NE	18.0	1.8	0.2
Fort Calhoun	NE	3.7	1.4	0.3
Hope Creek[b]	NJ	29.3	6.5	0.2
Oyster Creek[b]	NJ	6.0	17.4	5.1
Salem[b]	NJ	29.0	6.1	0.2
Indian Point[b]	NY	0.9	1.1	1.4
Peach Bottom	PA	29.4	18.5	6.6
Oconee	SC	8.2	3.3	0.0
Surry[b]	VA	37.1	12.0	0.3
Kewaunee[b]	WI	35.7	5.2	0.2
Point Beach[b]	WI	30.8	5.0	0.2

Notes: Urban areas have a population density greater than 1,284 people per square kilometer (3,326 people per square mile). Rural areas have a population density less than 54 people per square kilometer (139 people per square mile). Suburban areas have a population density between 54 and 1,284 people per square kilometer.

a. To convert kilometers to miles, multiply by 0.62137.

b. Could also ship by barge.

Table G-8. Distances for representative truck routes from generator sites to the repository.

Origin	Origin State	Rural kilometers[a]	Suburban kilometers[a]	Urban kilometers[a]
Crystal River	FL	3,552.8	834.3	113.9
Turkey Point	FL	3,910.8	998.7	154.8
Idaho National Laboratory	ID	951.0	196.9	48.0
Clinton	IL	2,636.6	394.7	51.4
Pilgrim	MA	3,480.3	1086.8	120.8
Cook	MI	2,654.5	452.1	65.8
Ginna	NY	3,139.4	824.1	109.6
Hanford Site	WA	1,531.1	286.6	59.9
LaCrosse	WI	2,616.0	328.5	55.7

Notes: Urban areas have a population density greater than 1,284 people per square kilometer (3,326 people per square mile). Rural areas have a population density less than 54 people per square kilometer (139 people per square mile). Suburban areas have a population density between 54 and 1,284 people per square kilometer.

a. To convert kilometers to miles, multiply by 0.62137.

Table G-9. Population escalation factors for 2000 to 2067.

States and counties	Population escalation factors	States and counties	Population escalation factors
Alabama	1.2277	Ohio	1.0174
Arkansas	1.4901	Oklahoma	1.3530
Arizona	4.9553	Oregon	2.2607
California	1.9439	Pennsylvania	1.0397
Colorado	1.9161	Rhode Island	1.0998
Connecticut	1.0831	South Carolina	1.6186
District of Columbia	0.7576	South Dakota	1.0604
Delaware	1.5200	Tennessee	1.7775
Florida	3.8088	Texas	2.8136
Georgia	2.1158	Utah	2.7680
Iowa	1.0099	Virginia	1.9803
Idaho	2.3948	Vermont	1.2790
Illinois	1.1383	Washington	2.5613
Indiana	1.2342	Wisconsin	1.2366
Kansas	1.1534	West Virginia	0.9511
Kentucky	1.2541	Wyoming	1.0591
Louisiana	1.1437	Nevada counties	
Massachusetts	1.1938	Churchill	2.2157
Maryland	1.7519	Clark	3.4982
Maine	1.1068	Elko	0.9005
Michigan	1.0760	Esmeralda	1.0219
Minnesota	1.6219	Eureka	0.7722
Missouri	1.3131	Humboldt	0.7332
Mississippi	1.1488	Lander	0.3521
Montana	1.2217	Lincoln	1.6673
North Carolina	2.4719	Lyon	4.8305
North Dakota	0.9445	Nye	3.9746
Nebraska	1.0965	Pershing	1.0541
New Hampshire	1.7545	Storey	2.9660
New Jersey	1.3217	Washoe	2.8725
New Mexico	1.1543	White Pine	0.6826
New York	1.0264	Mineral	0.7327

of rail and truck casks that would be shipped to the repository. From these estimates, there would be 9,495 rail casks and 2,650 truck casks shipped for the Proposed Action (DIRS 181377-BSC 2007, Section 7). Shipments of the 9,495 rail casks would use 2,833 trains. These estimates were based on 90-percent use of TAD canisters at the commercial sites.

G.4 Radionuclide Inventory

Appendix A of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. A-1 to A-71) provided the basis for the radionuclide inventory DOE used in the transportation analysis in the FEIS (DIRS 155970-DOE 2002, Chapter 6, Appendix J). Since the completion of the FEIS, DOE has updated these radionuclide inventories through additional data collection and analyses.

Table G-10. Updated cask shipment data.

Origin	Origin state	Fuel type	Mode	Casks containing uncanistered SNF	Casks containing TAD canisters	Casks containing other canisters	Total number of casks	Number of shipments
Browns Ferry	AL	BWR	Rail		245		245	82
Farley	AL	PWR	Rail		130		130	44
Arkansas	AR	PWR	Rail		107	20	127	43
Palo Verde	AZ	PWR	Rail		197	2	199	67
Diablo Canyon	CA	PWR	Rail		122		122	41
Humboldt Bay	CA	BWR	Rail			5	5	2
Rancho Seco	CA	PWR	Rail			21	21	7
San Onofre	CA	PWR	Rail		142	9	151	51
Haddam Neck	CT	PWR	Rail			40	40	14
Millstone	CT	BWR	Rail		66		66	22
Millstone	CT	PWR	Rail		110		110	37
Crystal River	FL	PWR	Truck	280			280	280
St. Lucie	FL	PWR	Rail		138		138	46
Turkey Point	FL	PWR	Truck	577			577	577
Hatch	GA	BWR	Rail		177		177	59
Vogtle	GA	PWR	Rail		115		115	39
Arnold	IA	BWR	Rail		58		58	20
Idaho National Laboratory	ID	BWR	Rail			2	2	1
Idaho National Laboratory	ID	DOE	Rail			179	179	36
Idaho National Laboratory	ID	Navy	Rail			400	400	80
Idaho National Laboratory	ID	PWR	Rail			7	7	2
Idaho National Laboratory	ID	HLW	Rail			106	106	22
Idaho National Laboratory	ID	BWR	Truck	1			1	1
Braidwood	IL	PWR	Rail		112		112	38
Byron	IL	PWR	Rail		122		122	41
Clinton	IL	BWR	Truck	327			327	327
Dresden	IL	BWR	Rail		181	14	195	65
LaSalle	IL	BWR	Rail		152		152	51
Morris	IL	BWR	Rail		67		67	23
Morris	IL	PWR	Rail		17		17	6
Quad Cities	IL	BWR	Rail		189		189	63
Zion	IL	PWR	Rail		106		106	36
Wolf Creek	KS	PWR	Rail		60		60	20
River Bend	LA	BWR	Rail		70		70	24
Waterford	LA	PWR	Rail		63		63	21
Pilgrim	MA	BWR	Truck	344			344	344

Table G-10. Updated cask shipment data (continued).

Origin	Origin state	Fuel type	Mode	Casks containing uncanistered SNF	Casks containing TAD canisters	Casks containing other canisters	Total number of casks	Number of shipments
Yankee Rowe	MA	PWR	Rail			15	15	5
Calvert Cliffs	MD	PWR	Rail		126	12	138	46
Maine Yankee	ME	PWR	Rail			60	60	20
Big Rock Point	MI	BWR	Rail			7	7	3
Cook	MI	PWR	Truck	768			768	768
Fermi	MI	BWR	Rail		63		63	21
Palisades	MI	PWR	Rail		50	12	62	21
Monticello	MN	BWR	Rail		44		44	15
Prairie Island	MN	PWR	Rail		109		109	37
Callaway	MO	PWR	Rail		73		73	25
Grand Gulf	MS	BWR	Rail		100		100	34
Brunswick	NC	BWR	Rail		83	1	84	28
Brunswick	NC	PWR	Rail		15		15	5
Harris	NC	BWR	Rail		64		64	22
Harris	NC	PWR	Rail		64		64	22
McGuire	NC	PWR	Rail		152		152	51
Cooper	NE	BWR	Rail		49		49	17
Fort Calhoun	NE	PWR	Rail		50		50	17
Seabrook	NH	PWR	Rail		50		50	17
Hope Creek	NJ	BWR	Rail		79		79	27
Oyster Creek	NJ	BWR	Rail		79		79	27
Salem	NJ	PWR	Rail		118		118	40
FitzPatrick	NY	BWR	Rail		76		76	26
Ginna	NY	PWR	Truck	313			313	313
Indian Point	NY	PWR	Rail		133		133	45
Nine Mile Point	NY	BWR	Rail		147		147	49
West Valley	NY	HLW	Rail			56	56	12
Davis-Besse	OH	PWR	Rail		51		51	17
Perry	OH	BWR	Rail		75		75	25
Trojan	OR	PWR	Rail			33	33	11
Beaver Valley	PA	PWR	Rail		102		102	34
Limerick	PA	BWR	Rail		155		155	52
Peach Bottom	PA	BWR	Rail		206		206	69
Susquehanna	PA	BWR	Rail		162		162	54
Three Mile Island	PA	PWR	Rail		53		53	18
Catawba	SC	PWR	Rail		123		123	41
Oconee	SC	PWR	Rail		138	48	186	62
Robinson	SC	PWR	Rail		26	5	31	11
Savannah River Site	SC	DOE	Rail			45	45	9

Table G-10. Updated cask shipment data (continued).

Origin	Origin state	Fuel type	Mode	Casks containing uncanistered SNF	Casks containing TAD canisters	Casks containing other canisters	Total number of casks	Number of shipments
Savannah River Site	SC	HLW	Rail			698	698	140
Summer	SC	PWR	Rail		55		55	19
Sequoyah	TN	PWR	Rail		120		120	40
Watts Bar	TN	PWR	Rail		30		30	10
Comanche Peak	TX	PWR	Rail		99		99	33
South Texas	TX	PWR	Rail		95		95	32
North Anna	VA	PWR	Rail		117		117	39
Surry	VA	PWR	Rail		121		121	41
Vermont Yankee	VT	BWR	Rail		74		74	25
Columbia	WA	BWR	Rail		66	3	69	23
Hanford Site	WA	DOE	Rail			141	141	29
Hanford Site	WA	HLW	Rail			1064	1064	213
Hanford Site	WA	BWR	Truck	1			1	1
Hanford Site	WA	PWR	Truck	2			2	2
Kewaunee	WI	PWR	Rail		54		54	18
LaCrosse	WI	BWR	Truck	37			37	37
Point Beach	WI	PWR	Rail		98		98	33

Source: DIRS 181377-BSC 2007, Section 7.

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

The primary sources of the new radionuclide inventory information are:

- *PWR Source Term Generation and Evaluation* (DIRS 169061-BSC 2004, all),
- *BWR Source Term Generation and Evaluation* (DIRS 164364-BSC 2003, all),
- *Source Term Estimates for DOE Spent Nuclear Fuels* (DIRS 169354-DOE 2004, all), and
- *Recommended Values for HLW Glass for Consistent Usage on the Yucca Mountain Project* (DIRS 184907-BSC 2008, all).

The radionuclide inventory DOE used in this Repository SEIS represents the radioactivity contained in about 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste that would be shipped to the repository. Tables G-11 through G-16 list the updated radionuclide inventories.

DOE spent nuclear fuel was organized into 34 groups based on the fuel compound, fuel enrichment, fuel cladding material, and fuel cladding condition (DIRS 171271-DOE 2004, all). The characteristics of the spent nuclear fuel, including percent enrichment, decay time, and burnup, would affect the radionuclide

Table G-11. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 1 through 8.

	Uranium metal				Uranium oxide			
					Zirconium clad (intact)			Stainless-steel/Hastelloy clad (intact)
Radionuclide	Zirconium-clad LEU Group	Non-Zirconium-clad LEU Group 2	Uranium-zirconium Group 3	Uranium-molybdenum Group 4	HEU Group 5	MEU Group 6	LEU Group 7	HEU Group 8
Actinium-227	5.0×10^{-3}	5.8×10^{-4}	3.0×10^{-3}	8.4×10^{-3}	5.4×10^{-3}	2.9×10^{-5}	4.2×10^{-3}	1.0×10^{-4}
Americium-241	7.1×10^{5}	2.1×10^{4}	1.4×10^{4}	1.8×10^{2}	4.6×10^{2}	4.8×10^{3}	3.7×10^{5}	4.6×10^{-1}
Americium-242m	4.4×10^{2}	3.4×10^{1}	2.2	2.8×10^{-2}	8.6×10^{-1}	9.7	7.8×10^{2}	3.5×10^{-5}
Americium-243	3.7×10^{2}	6.4	1.3	1.6×10^{-2}	1.8	2.1×10^{1}	1.7×10^{3}	4.1×10^{-6}
Carbon-14	1.1×10^{3}	2.0×10^{3}	7.0×10^{2}	1.1×10^{1}	5.3×10^{1}	1.6	6.6×10^{2}	9.5×10^{-1}
Chlorine-36	5.2×10^{-2}	3.7×10^{1}	1.2×10^{-3}	4.8×10^{-3}	2.8×10^{-1}	2.7×10^{-2}	2.1	5.1×10^{-3}
Curium-243	1.7×10^{1}	6.6	3.1×10^{-1}	4.0×10^{-3}	7.5×10^{-1}	8.7	7.6×10^{2}	9.8×10^{-7}
Curium-244	6.5×10^{3}	8.9×10^{1}	6.5	8.3×10^{-2}	1.5×10^{2}	1.7×10^{3}	1.6×10^{5}	8.9×10^{-6}
Cobalt-60	2.7×10^{4}	4.6×10^{5}	4.0×10^{4}	6.8×10^{2}	1.6×10^{4}	1.2×10^{2}	4.7×10^{4}	2.5×10^{2}
Cesium-134	1.1×10^{2}	1.5×10^{2}	5.0	1.2×10^{-1}	1.8	1.9×10^{1}	2.6×10^{3}	1.0×10^{-2}
Cesium-135	7.6×10^{1}	1.9	5.0	4.0	7.0	4.9×10^{-1}	4.2×10^{1}	1.3×10^{-1}
Cesium-137	9.3×10^{6}	2.2×10^{5}	9.0×10^{5}	1.3×10^{5}	3.4×10^{5}	4.8×10^{4}	4.9×10^{6}	5.7×10^{3}
Europium-154	5.2×10^{4}	1.2×10^{3}	4.2×10^{3}	6.9×10^{1}	2.3×10^{2}	7.8×10^{2}	9.1×10^{4}	2.4
Europium-155	2.5×10^{3}	7.7×10^{2}	3.9×10^{2}	1.3×10^{2}	1.7×10^{2}	8.5×10^{1}	1.2×10^{4}	2.5
Iron-55	4.7×10^{1}	6.2×10^{3}	3.7×10^{1}	1.7	2.8×10^{2}	6.8	1.1×10^{3}	4.2
Hydrogen-3	2.6×10^{4}	4.2×10^{3}	1.5×10^{4}	4.9×10^{2}	6.5×10^{2}	7.6×10^{2}	8.7×10^{4}	9.4
Iodine-129	6.5	1.3×10^{-1}	4.7×10^{-1}	1.1×10^{-1}	1.7×10^{-1}	3.3×10^{-2}	2.9	3.0×10^{-3}
Krypton-85	2.1×10^{5}	7.5×10^{3}	2.4×10^{4}	3.7×10^{3}	9.6×10^{3}	1.0×10^{3}	1.3×10^{5}	1.5×10^{2}
Neptunium-237	6.4×10^{1}	1.9	3.5	3.3×10^{-1}	3.0×10^{-1}	3.8×10^{-1}	3.1×10^{1}	4.8×10^{-3}
Protactinium-231	1.2×10^{-2}	1.1×10^{-3}	5.0×10^{-3}	1.7×10^{-2}	1.0×10^{-2}	4.3×10^{-5}	6.9×10^{-3}	2.0×10^{-4}
Lead-210	2.0×10^{-3}	3.6×10^{-4}	2.7×10^{-3}	3.5×10^{-5}	3.7×10^{-7}	2.7×10^{-6}	2.2×10^{-3}	3.1×10^{-9}
Promethium-147	4.7×10^{3}	1.6×10^{4}	6.2×10^{2}	1.1×10^{2}	2.8×10^{2}	5.6×10^{1}	8.9×10^{3}	4.0
Plutonium-238	1.5×10^{5}	3.6×10^{3}	4.0×10^{3}	6.5×10^{1}	2.9×10^{2}	2.5×10^{3}	2.1×10^{5}	1.2
Plutonium-239	2.2×10^{5}	7.1×10^{3}	1.2×10^{4}	1.8×10^{3}	2.0×10^{2}	3.9×10^{2}	4.0×10^{4}	2.8
Plutonium-240	1.7×10^{5}	3.5×10^{3}	5.2×10^{3}	7.1×10^{1}	7.3×10^{1}	5.1×10^{2}	4.4×10^{4}	3.6×10^{-1}
Plutonium-241	4.5×10^{6}	1.4×10^{5}	9.1×10^{4}	1.1×10^{3}	3.5×10^{3}	3.2×10^{4}	3.2×10^{6}	2.7
Plutonium-242	1.1×10^{2}	1.9	1.3	1.6×10^{-2}	1.9×10^{-1}	2.2	1.7×10^{2}	8.2×10^{-6}

Table G-11. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 1 through 8 (continued).

	Uranium metal				Uranium oxide			
					Zirconium clad (intact)			Stainless-steel/Hastelloy clad (intact)
Radionuclide	Zirconium-clad LEU Group 1	Non-Zirconium-clad LEU Group 2	Uranium-zirconium Group 3	Uranium-molybdenum Group 4	HEU Group 5	MEU Group 6	LEU Group 7	HEU Group 8
Radium-226	5.6×10^{-3}	9.7×10^{-4}	7.4×10^{-3}	9.4×10^{-5}	1.0×10^{-6}	7.3×10^{-6}	6.0×10^{-3}	8.2×10^{-9}
Radium-228	4.9×10^{-4}	2.4×10^{-5}	7.4×10^{-4}	1.1×10^{-5}	1.9×10^{-6}	1.8×10^{-7}	5.7×10^{-4}	3.4×10^{-8}
Ruthenium-106	4.4×10^{-3}	1.1×10^{3}	2.1×10^{-4}	2.9×10^{-5}	2.1×10^{-3}	2.6×10^{-1}	5.1×10^{2}	6.3×10^{-7}
Selenium-79	8.4×10^{1}	3.1	7.8	1.5	3.1	4.2×10^{-1}	3.9×10^{1}	5.5×10^{-2}
Tin-126	6.6	2.5	7.5	3.4	2.7	8.5×10^{-1}	7.2×10^{1}	4.8×10^{-2}
Strontium-90	6.7×10^{6}	1.6×10^{5}	7.9×10^{5}	1.1×10^{5}	3.2×10^{5}	3.2×10^{4}	3.4×10^{6}	5.4×10^{3}
Technetium-99	2.8×10^{3}	5.9×10^{1}	2.8×10^{2}	4.2×10^{1}	1.1×10^{2}	1.3×10^{1}	1.2×10^{3}	1.9
Thorium-229	1.8×10^{-3}	1.8×10^{-4}	2.7×10^{-3}	3.8×10^{-5}	3.7×10^{-6}	4.0×10^{-6}	2.3×10^{-3}	6.4×10^{-8}
Thorium-230	5.6×10^{-1}	8.8×10^{-2}	6.7×10^{-1}	8.6×10^{-3}	9.6×10^{-5}	6.9×10^{-4}	5.5×10^{-1}	7.3×10^{-7}
Thorium-232	4.9×10^{-4}	2.4×10^{-5}	7.5×10^{-4}	1.1×10^{-5}	1.9×10^{-6}	1.8×10^{-7}	5.8×10^{-4}	3.5×10^{-8}
Thallium-208	3.0×10^{-2}	2.0×10^{-2}	2.9×10^{-2}	8.7×10^{-4}	5.5×10^{-3}	6.0×10^{-3}	5.1×10^{-1}	8.8×10^{-5}
Uranium-232	8.2×10^{-2}	5.4×10^{-2}	7.8×10^{-2}	2.3×10^{-3}	1.5×10^{-2}	1.6×10^{-2}	1.4	2.4×10^{-4}
Uranium-233	3.9×10^{-1}	3.9×10^{-2}	5.7×10^{-1}	8.0×10^{-3}	8.0×10^{-4}	8.5×10^{-4}	5.0×10^{-1}	1.3×10^{-5}
Uranium-234	1.4×10^{3}	1.9×10^{2}	1.5×10^{3}	1.9×10^{1}	2.6×10^{-1}	1.7	1.2×10^{3}	1.6×10^{-3}
Uranium-235	4.8×10^{1}	8.2×10^{-2}	6.0×10^{-3}	2.0	9.9×10^{-1}	2.0×10^{-1}	2.3	3.9×10^{-1}
Uranium-236	9.7×10^{1}	2.8	1.7×10^{1}	1.3	3.7	2.6×10^{-1}	3.3×10^{1}	6.7×10^{-2}
Uranium-238	7.0×10^{2}	2.1	3.3×10^{-1}	1.0	2.1×10^{-2}	6.0×10^{-1}	3.0×10^{1}	4.7×10^{-3}

Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.
HEU = Highly enriched uranium.
LEU = Low-enriched uranium.
MEU = Medium-enriched uranium.

Table G-12. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 9 through 16.

	Uranium oxide							Uranium-aluminum
	Stainless-steel clad (Intact)		Non-aluminum clad Non-intact or declad			Aluminum clad		
Radionuclide	MEU Group 9	LEU Group 10	HEU Group 11	MEU Group 12	LEU Group 13	HEU Group 14	MEU and LEU Group 15	HEU Group 16
Actinium-227	1.4×10^{-4}	9.5×10^{-4}	5.6×10^{-3}	8.5×10^{-4}	4.2×10^{-3}	8.8×10^{-4}	1.3×10^{-5}	1.0×10^{-3}
Americium-241	1.1	1.8×10^{4}	1.9×10^{4}	1.5×10^{3}	4.7×10^{4}	4.9×10^{3}	4.8×10^{1}	5.2×10^{3}
Americium-242m	1.1×10^{-4}	8.8	3.8×10^{1}	3.0	1.1×10^{2}	9.9×10^{-1}	1.6×10^{-2}	1.6
Americium-243	1.2×10^{-5}	4.5	3.7×10^{1}	6.5	2.3×10^{2}	1.5×10^{1}	5.4×10^{-2}	1.8×10^{1}
Carbon-14	2.7	1.9×10^{3}	2.8×10^{2}	1.5×10^{1}	8.5×10^{1}	1.6×10^{-2}	2.1×10^{-4}	3.0×10^{-1}
Chlorine-36	1.5×10^{-2}	3.6×10^{1}	5.2	8.4×10^{-2}	6.5×10^{-1}	1.7×10^{-25}	4.7×10^{-28}	2.7×10^{-4}
Curium-243	4.2×10^{-6}	1.4	2.0	2.7	1.1×10^{2}	2.5	7.9×10^{-3}	3.7
Curium-244	4.9×10^{-5}	6.3×10^{1}	3.9×10^{2}	5.3×10^{2}	2.6×10^{4}	2.1×10^{3}	1.7	3.3×10^{3}
Cobalt-60	1.1×10^{4}	4.4×10^{5}	1.0×10^{5}	1.6×10^{4}	8.1×10^{4}	5.1×10^{1}	1.1	3.6×10^{2}
Cesium-134	1.7×10^{2}	5.2	6.8×10^{2}	7.1	4.4×10^{2}	7.4×10^{4}	1.3×10^{4}	1.3×10^{6}
Cesium-135	3.6×10^{-1}	1.1	1.8	2.0	1.4×10^{1}	5.5	1.2×10^{-1}	9.7
Cesium-137	2.4×10^{4}	1.6×10^{5}	1.0×10^{5}	1.3×10^{5}	1.2×10^{6}	3.2×10^{6}	9.6×10^{4}	6.9×10^{6}
Europium-154	3.2×10^{1}	8.1×10^{2}	3.0×10^{3}	3.3×10^{2}	1.7×10^{4}	5.9×10^{4}	2.5×10^{3}	2.1×10^{5}
Europium-155	1.3×10^{2}	2.4×10^{2}	6.1×10^{2}	2.0×10^{2}	3.4×10^{3}	2.0×10^{4}	1.1×10^{3}	1.1×10^{5}
Iron-55	8.5×10^{3}	4.6×10^{3}	3.5×10^{4}	1.1×10^{3}	5.4×10^{3}	4.6×10^{3}	1.9×10^{2}	3.7×10^{4}
Hydrogen-3	7.3×10^{1}	3.9×10^{3}	7.3×10^{2}	5.1×10^{2}	1.4×10^{4}	7.5×10^{3}	3.3×10^{2}	2.3×10^{4}
Iodine-129	8.7×10^{-3}	9.7×10^{-2}	4.4×10^{-2}	5.6×10^{-2}	5.7×10^{-1}	1.1	2.7×10^{-2}	2.0
Krypton-85	1.4×10^{3}	4.4×10^{3}	4.8×10^{3}	5.2×10^{3}	4.2×10^{4}	1.8×10^{5}	8.9×10^{3}	6.0×10^{5}
Neptunium-237	1.4×10^{-2}	1.7	4.5×10^{-1}	1.9×10^{-1}	4.1	2.2×10^{1}	3.4×10^{-1}	3.4×10^{1}
Protactinium-231	3.4×10^{-4}	2.0×10^{-3}	7.3×10^{-3}	2.0×10^{-3}	9.9×10^{-3}	2.7×10^{-3}	4.6×10^{-5}	3.5×10^{-3}
Lead-210	2.4×10^{-9}	3.5×10^{-4}	5.5×10^{-5}	8.4×10^{-7}	1.2×10^{-5}	6.4×10^{-5}	1.4×10^{-6}	8.7×10^{-5}
Promethium-147	7.5×10^{3}	1.7×10^{3}	3.0×10^{4}	1.0×10^{3}	6.6×10^{3}	1.4×10^{5}	7.1×10^{4}	4.2×10^{6}
Plutonium-238	3.9	3.1×10^{3}	7.1×10^{3}	8.0×10^{2}	2.9×10^{4}	7.8×10^{4}	7.2×10^{2}	1.1×10^{5}
Plutonium-239	8.0	5.7×10^{3}	9.7×10^{2}	1.6×10^{2}	4.4×10^{3}	7.4×10^{2}	1.5×10^{1}	1.3×10^{3}
Plutonium-240	1.0	2.3×10^{3}	6.7×10^{2}	1.6×10^{2}	5.5×10^{3}	4.1×10^{2}	8.8	7.1×10^{2}
Plutonium-241	1.8×10^{1}	1.2×10^{5}	1.1×10^{5}	1.0×10^{4}	5.2×10^{5}	1.0×10^{5}	2.2×10^{3}	2.3×10^{5}
Plutonium-242	2.4×10^{-5}	1.4	5.6	6.7×10^{-1}	2.3×10^{1}	1.5	1.3×10^{-2}	2.0

Table G-12. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 9 through 16 (continued).

Radionuclide	Uranium oxide							Uranium-aluminum
	Stainless-steel Clad (intact)		Non-aluminum clad Non-intact or declad			Aluminum clad		
	MEU Group 9	LEU Group 10	HEU Group 11	MEU Group 12	LEU Group 13	HEU Group 14	MEU and LEU Group 15	HEU Group 16
Radium-226	8.5×10^{-9}	9.4×10^{-4}	1.5×10^{-4}	2.3×10^{-6}	4.2×10^{-5}	2.9×10^{-4}	4.8×10^{-6}	3.6×10^{-4}
Radium-228	9.2×10^{-8}	1.9×10^{-5}	1.4×10^{-3}	5.6×10^{-7}	4.3×10^{-6}	1.9×10^{-8}	2.3×10^{-10}	1.2×10^{-6}
Ruthenium-106	3.8×10^{2}	2.1	1.6×10^{3}	3.3×10^{-2}	2.7×10^{-1}	1.6×10^{3}	5.1×10^{3}	3.6×10^{5}
Selenium-79	1.6×10^{-1}	2.7	7.9×10^{-1}	9.5×10^{-1}	8.3	1.9×10^{1}	4.7×10^{-1}	3.4×10^{1}
Tin-126	1.4×10^{-1}	2.0	6.9×10^{-1}	9.8×10^{-1}	1.2×10^{1}	1.7×10^{1}	4.2×10^{-1}	3.0×10^{1}
Strontium-90	2.3×10^{4}	1.2×10^{5}	9.6×10^{4}	1.2×10^{5}	9.3×10^{5}	3.0×10^{6}	9.2×10^{4}	6.5×10^{6}
Technetium-99	5.6	4.7×10^{1}	2.8×10^{1}	3.3×10^{1}	2.8×10^{2}	6.2×10^{2}	1.5×10^{1}	1.1×10^{3}
Thorium-229	1.0×10^{-7}	1.7×10^{-4}	4.0×10^{-3}	1.8×10^{-6}	3.4×10^{-5}	7.6×10^{-6}	1.1×10^{-7}	9.7×10^{-6}
Thorium-230	1.2×10^{-6}	8.6×10^{-2}	1.3×10^{-2}	2.2×10^{-4}	5.3×10^{-3}	5.2×10^{-2}	9.1×10^{-4}	6.8×10^{-2}
Thorium-232	9.9×10^{-8}	1.9×10^{-5}	1.4×10^{-3}	5.7×10^{-7}	4.4×10^{-6}	2.9×10^{-8}	4.2×10^{-10}	1.5×10^{-6}
Thallium-208	2.9×10^{-4}	1.3×10^{-2}	2.0×10^{-1}	3.3×10^{-3}	7.6×10^{-2}	7.0×10^{-2}	1.6×10^{-3}	1.2×10^{-1}
Uranium-232	8.0×10^{-4}	3.6×10^{-2}	5.4×10^{-1}	9.0×10^{-3}	2.1×10^{-1}	1.9×10^{-1}	4.7×10^{-3}	3.4×10^{-1}
Uranium-233	3.7×10^{-5}	3.6×10^{-2}	8.2×10^{-1}	4.5×10^{-4}	9.7×10^{-3}	4.2×10^{-3}	7.8×10^{-5}	6.7×10^{-3}
Uranium-234	4.4×10^{-3}	1.9×10^{2}	2.9×10^{1}	5.4×10^{-1}	1.7×10^{1}	2.3×10^{2}	6.6	4.3×10^{2}
Uranium-235	2.7×10^{-1}	1.8×10^{-1}	2.4	1.3×10^{-1}	4.6	7.8	6.2×10^{-2}	1.3×10^{1}
Uranium-236	1.9×10^{-1}	2.6	9.8×10^{-1}	1.1	7.5	2.4×10^{1}	5.6×10^{-1}	4.2×10^{1}
Uranium-238	1.9×10^{-1}	2.6×10^{-1}	3.6×10^{-1}	1.3×10^{-1}	2.7×10^{1}	1.3×10^{-1}	8.3×10^{-2}	3.2×10^{-1}

Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.
HEU = Highly enriched uranium.
LEU = Low-enriched uranium.
MEU= Medium-enriched uranium.

Table G-13. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 17 through 24.

			Thorium/uranium carbide		Plutonium/ uranium carbide	Mixed oxide		
Radionuclide	Uranium-aluminum MEU Group 17	Uranium silicide Group 18	TRISO or BISO particles in graphite Group 19	Mono-pyrolytic carbon particles Group 20	Non-graphite non-sodium bonded Group 21	Zirconium clad Group 22	Stainless-steel clad Group 23	Non-stainless steel Non-zirconium clad Group 24
Actinium-227	6.1×10^{-5}	2.7×10^{-4}	2.6	2.3×10^{-1}	2.1×10^{-8}	1.6×10^{-1}	4.2×10^{-2}	4.9×10^{-3}
Americium-241	1.9×10^{3}	8.6×10^{3}	2.3×10^{3}	1.8×10^{2}	8.9×10^{2}	5.8×10^{5}	2.5×10^{5}	3.0×10^{4}
Americium-242m	1.3	6.1	2.2	1.4×10^{-1}	1.7×10^{1}	1.2×10^{3}	2.1×10^{3}	2.8×10^{2}
Americium-243	1.1	4.4	4.0×10^{1}	2.7	9.0×10^{-1}	1.1×10^{3}	4.4×10^{2}	6.1×10^{1}
Carbon-14	3.0×10^{-2}	1.2	2.0×10^{1}	1.4	2.2×10^{-1}	8.3×10^{3}	2.6×10^{3}	3.7×10^{2}
Chlorine-36	2.5×10^{-5}	1.2×10^{-3}	9.2×10^{-1}	6.2×10^{-2}	2.9×10^{-6}	1.6×10^{2}	4.9×10^{1}	7.0
Curium-243	4.3×10^{-1}	2.0	3.0×10^{1}	1.5	4.9	7.7×10^{1}	5.8×10^{2}	7.4×10^{1}
Curium-244	3.3×10^{1}	1.3×10^{2}	9.0×10^{3}	3.8×10^{2}	2.1×10^{1}	1.2×10^{4}	7.7×10^{3}	1.2×10^{3}
Cobalt-60	3.0×10^{1}	9.1×10^{2}	2.3×10^{3}	2.7×10^{1}	8.9×10^{1}	1.9×10^{6}	3.5×10^{6}	6.4×10^{5}
Cesium-134	1.3×10^{5}	2.6×10^{5}	3.7×10^{3}	1.5×10^{1}	2.0×10^{2}	9.4×10^{1}	4.1×10^{4}	5.1×10^{3}
Cesium-135	1.3	4.8	2.1×10^{1}	1.4	4.0×10^{-1}	3.2×10^{1}	4.9×10^{1}	6.4
Cesium-137	9.1×10^{5}	2.5×10^{6}	1.5×10^{6}	7.8×10^{4}	1.6×10^{4}	1.5×10^{6}	2.3×10^{6}	3.2×10^{5}
Europium-154	2.4×10^{4}	9.2×10^{4}	3.9×10^{4}	9.3×10^{2}	3.0×10^{2}	8.6×10^{4}	1.1×10^{5}	1.8×10^{4}
Europium-155	1.1×10^{4}	3.7×10^{4}	5.9×10^{3}	6.3×10^{1}	3.8×10^{2}	5.3×10^{3}	6.7×10^{4}	9.0×10^{3}
Iron-55	1.0×10^{4}	4.7×10^{4}	1.6	5.3×10^{-3}	2.6×10^{1}	2.0×10^{4}	4.8×10^{5}	5.5×10^{4}
Hydrogen-3	3.3×10^{3}	8.8×10^{3}	6.9×10^{3}	2.3×10^{2}	6.0×10^{1}	1.7×10^{4}	1.7×10^{4}	2.7×10^{3}
Iodine-129	2.4×10^{-1}	6.6×10^{-1}	8.7×10^{-1}	5.9×10^{-2}	1.1×10^{-2}	7.8×10^{-1}	1.3	1.7×10^{-1}
Krypton-85	8.7×10^{4}	2.2×10^{5}	7.9×10^{4}	2.3×10^{3}	4.7×10^{2}	4.2×10^{4}	8.5×10^{4}	1.2×10^{4}
Neptunium-237	2.3	4.7	1.1×10^{1}	7.3×10^{-1}	2.5×10^{-2}	1.1×10^{1}	5.6	7.6×10^{-1}
Protactinium-231	3.4×10^{-4}	1.2×10^{-3}	4.1	2.8×10^{-1}	5.7×10^{-8}	2.0×10^{-1}	6.1×10^{-2}	8.7×10^{-3}
Lead-210	1.0×10^{-6}	1.2×10^{-5}	7.3×10^{-4}	8.3×10^{-5}	4.1×10^{-9}	1.6×10^{-3}	3.2×10^{-4}	1.1×10^{-5}
Promethium-147	7.5×10^{5}	1.8×10^{6}	5.2×10^{3}	1.7×10^{1}	1.1×10^{3}	1.9×10^{3}	2.2×10^{5}	2.8×10^{4}
Plutonium-238	4.8×10^{3}	8.8×10^{3}	1.5×10^{5}	9.5×10^{3}	2.2×10^{2}	1.5×10^{5}	3.8×10^{4}	3.0×10^{3}
Plutonium-239	1.3×10^{3}	6.7×10^{3}	1.2×10^{2}	7.9	1.0×10^{3}	2.2×10^{4}	1.5×10^{5}	0.0

Table G-13. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 17 through 24 (continued).

			Thorium/uranium carbide		Plutonium/ uranium carbide	Mixed oxide		
Radionuclide	Uranium-aluminum MEU Group 17	Uranium silicide Group 18	TRISO or BISO particles in graphite Group 19	Mono-pyrolytic carbon particles Group 20	Non-graphite non-sodium bonded Group 21	Zirconium clad Group 22	Stainless-steel clad Group 23	Non-stainless steel non-zirconium clad Group 24
Plutonium-240	7.1×10^{2}	3.5×10^{3}	2.2×10^{2}	1.6×10^{1}	8.4×10^{2}	1.3×10^{4}	1.1×10^{5}	3.9×10^{3}
Plutonium-241	1.0×10^{5}	4.9×10^{5}	3.1×10^{4}	1.1×10^{3}	2.3×10^{4}	1.3×10^{6}	4.2×10^{6}	2.6×10^{4}
Plutonium-242	4.5×10^{-1}	2.0	3.4	2.3×10^{-1}	2.7×10^{-1}	1.3×10^{2}	4.4×10^{1}	1.8
Radium-226	9.0×10^{-6}	4.7×10^{-5}	1.2×10^{-3}	1.6×10^{-4}	1.5×10^{-8}	4.4×10^{-3}	9.2×10^{-4}	5.1×10^{-5}
Radium-228	1.2×10^{-7}	4.9×10^{-6}	7.8×10^{-1}	5.4×10^{-2}	8.1×10^{-13}	4.1×10^{-2}	1.2×10^{-2}	1.7×10^{-3}
Ruthenium-106	6.4×10^{4}	1.7×10^{5}	6.5×10^{-1}	7.9×10^{-2}	5.9×10^{1}	7.4×10^{-1}	1.2×10^{4}	1.5×10^{3}
Selenium-79	4.1	1.1×10^{1}	1.8×10^{1}	1.2	8.5×10^{-2}	1.4×10^{1}	1.3×10^{1}	1.7
Tin-126	3.7	1.0×10^{1}	1.9×10^{1}	1.3	3.7×10^{-1}	1.3×10^{1}	4.0×10^{1}	5.2
Strontium-90	8.6×10^{5}	2.3×10^{6}	1.5×10^{6}	7.4×10^{4}	5.8×10^{3}	1.4×10^{6}	1.2×10^{6}	1.7×10^{5}
Technetium-99	1.4×10^{2}	3.9×10^{2}	2.9×10^{2}	1.9×10^{1}	3.3	4.8×10^{2}	4.8×10^{2}	6.2×10^{1}
Thorium-229	5.5×10^{-7}	5.1×10^{-6}	5.8	6.2×10^{-1}	1.6×10^{-8}	1.2×10^{-1}	2.9×10^{-2}	2.7×10^{-3}
Thorium-230	3.6×10^{-3}	8.4×10^{-3}	1.2×10^{-1}	1.1×10^{-2}	3.1×10^{-6}	4.0×10^{-1}	9.6×10^{-2}	9.1×10^{-3}
Thorium-232	1.4×10^{-7}	6.4×10^{-6}	2.5	1.7×10^{-1}	1.2×10^{-12}	4.1×10^{-2}	1.3×10^{-2}	1.8×10^{-3}
Thallium-208	9.8×10^{-3}	1.7×10^{-2}	5.8×10^{2}	3.5×10^{1}	4.3×10^{-3}	6.0	2.5	3.7×10^{-1}
Uranium-232	2.9×10^{-2}	4.8×10^{-2}	1.6×10^{3}	9.4×10^{1}	1.2×10^{-2}	1.6×10^{1}	6.7	1.0
Uranium-233	5.0×10^{-4}	4.3×10^{-3}	1.8×10^{3}	1.2×10^{2}	2.5×10^{-6}	2.5×10^{1}	7.7	1.1
Uranium-234	3.7×10^{1}	4.7×10^{1}	2.4×10^{2}	1.7×10^{1}	2.2×10^{-2}	8.7×10^{2}	2.7×10^{2}	3.9×10^{1}
Uranium-235	4.4×10^{-1}	1.2	3.6	2.4×10^{-1}	1.9×10^{-4}	4.0×10^{1}	1.2×10^{1}	1.8
Uranium-236	4.7	1.2×10^{1}	7.4	5.0×10^{-1}	1.1×10^{-3}	1.6×10^{1}	5.1	7.3×10^{-1}
Uranium-238	7.9×10^{-1}	2.2	4.5×10^{-2}	3.0×10^{-3}	1.8×10^{-2}	8.0	5.0	3.9×10^{-1}

Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.

HEU = Highly enriched uranium.

LEU = Low-enriched uranium.

MEU= Medium-enriched uranium.

Table G-14. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 25 through 30, 32, and 34.

			Uranium/zirconium hydride					
	Thorium/uranium oxide		Stainless steel/Incoloy clad		Aluminum clad			
Radionuclide	Zirconium clad Group 25	Stainless-steel clad Group 26	HEU Group 27	MEU Group 28	MEU Group 29	Declad Group 30	Naval spent nuclear fuel Group 32[a]	Miscellaneous Group 34
Actinium-227	3.9×10^{1}	7.4	2.1×10^{-5}	6.5×10^{-5}	2.1×10^{-5}	2.7×10^{-4}	3.9×10^{-2}	5.0×10^{-3}
Americium-241	1.1×10^{2}	7.1×10^{3}	3.8×10^{2}	1.1×10^{2}	3.0×10^{1}	1.1×10^{2}	2.0×10^{4}	2.7×10^{3}
Americium-242m	7.3×10^{-1}	1.6×10^{1}	8.2×10^{-1}	7.2×10^{-2}	1.9×10^{-2}	3.3×10^{-2}	1.8×10^{2}	6.9
Americium-243	1.5×10^{-1}	1.5×10^{1}	1.1	7.7×10^{-3}	2.4×10^{-3}	4.2×10^{-3}	2.7×10^{2}	1.5×10^{1}
Carbon-14	4.4×10^{1}	1.2×10^{2}	4.4	6.7	4.4×10^{-1}	3.6	6.4×10^{3}	3.9×10^{1}
Californium-252	0.0	0.0	0.0	0.0	0.0	0.0	4.8×10^{-4}	0.0
Chlorine-36	8.5×10^{-1}	2.2	9.3×10^{-2}	1.5×10^{-1}	4.3×10^{-4}	8.0×10^{-2}	2.8×10^{2}	7.0×10^{-1}
Curium-242	0.0	0.0	0.0	0.0	0.0	0.0	5.6×10^{2}	0.0
Curium-243	1.8×10^{-1}	1.0	1.1	8.8×10^{-3}	2.4×10^{-3}	1.7×10^{-3}	3.2×10^{2}	8.1×10^{-1}
Curium-244	9.8	2.2×10^{2}	1.1×10^{2}	8.2×10^{-2}	2.6×10^{-2}	8.6×10^{-3}	2.5×10^{4}	5.4×10^{1}
Curium-245	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0
Curium-246	0.0	0.0	0.0	0.0	0.0	0.0	5.6×10^{-1}	0.0
Curium-247	0.0	0.0	0.0	0.0	0.0	0.0	3.8×10^{-6}	0.0
Curium-248	0.0	0.0	0.0	0.0	0.0	0.0	1.0×10^{-5}	0.0
Cobalt-60	1.5×10^{3}	9.5×10^{4}	2.3×10^{4}	5.8×10^{4}	2.2×10^{2}	9.8×10^{1}	1.5×10^{6}	1.1×10^{4}
Cobalt-60 (Crud)	0.0	0.0	0.0	0.0	0.0	0.0	2.3×10^{3}	0.0
Cesium-134	3.5×10^{2}	1.1×10^{1}	9.8×10^{3}	4.0×10^{3}	7.1×10^{2}	7.0×10^{-4}	3.4×10^{7}	8.8×10^{1}
Cesium-135	1.3×10^{1}	2.6	6.9×10^{-1}	1.7	3.2×10^{-1}	9.1×10^{-1}	1.8×10^{3}	4.4
Cesium-137	8.8×10^{5}	1.4×10^{5}	8.0×10^{4}	1.4×10^{5}	2.4×10^{4}	2.8×10^{4}	1.8×10^{8}	2.1×10^{5}
Europium-154	9.1×10^{3}	3.2×10^{3}	2.7×10^{3}	7.1×10^{2}	1.0×10^{4}	1.2×10^{1}	0.0	5.1×10^{2}
Europium-155	1.3×10^{3}	3.0×10^{2}	9.8×10^{2}	1.3×10^{3}	3.1×10^{3}	1.6	0.0	2.3×10^{3}
Iron-55	1.6×10^{1}	3.8×10^{3}	1.2×10^{4}	3.4×10^{4}	6.0×10^{1}	1.4×10^{-1}	0.0	3.7×10^{2}
Hydrogen-3	1.8×10^{3}	5.5×10^{2}	2.5×10^{2}	5.2×10^{2}	8.5×10^{1}	2.5×10^{1}	5.6×10^{5}	1.1×10^{3}
Iodine-129	7.5×10^{-1}	1.3×10^{-1}	2.5×10^{-2}	3.8×10^{-2}	7.4×10^{-3}	2.1×10^{-2}	4.8×10^{1}	1.1×10^{-1}
Krypton-85	5.6×10^{4}	5.8×10^{3}	5.8×10^{3}	1.2×10^{4}	1.9×10^{3}	3.9×10^{2}	1.4×10^{7}	1.3×10^{4}

Table G-14. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 25 through 30, 32, and 34 (continued).

			Uranium/zirconium hydride					
	Thorium/uranium oxide		Stainless steel/Incoloy clad		Aluminum clad			
Radionuclide	Zirconium clad Group 25	Stainless-steel clad Group 26	HEU Group 27	MEU Group 28	MEU Group 29	Declad Group 30	Naval spent nuclear fuel Group 32[a]	Miscellaneous Group 34
Niobium-93m	0.0	0.0	0.0	0.0	0.0	0.0	1.4×10^{3}	0.0
Niobium-94	0.0	0.0	0.0	0.0	0.0	0.0	7.2×10^{4}	0.0
Nickel-59	0.0	0.0	0.0	0.0	0.0	0.0	2.5×10^{4}	0.0
Nickel-63	0.0	0.0	0.0	0.0	0.0	0.0	3.1×10^{6}	0.0
Neptunium-237	5.9×10^{-2}	1.5×10^{-1}	4.2×10^{-1}	6.5×10^{-2}	1.5×10^{-2}	3.7×10^{-2}	6.4×10^{2}	3.6×10^{-1}
Protactinium-231	5.7×10^{1}	9.1	5.3×10^{-5}	2.3×10^{-4}	5.6×10^{-5}	4.4×10^{-4}	2.1×10^{-1}	1.2×10^{-2}
Lead-210	5.6×10^{-3}	1.1×10^{-3}	1.9×10^{-8}	1.2×10^{-9}	9.8×10^{-10}	2.0×10^{-8}	3.6×10^{-4}	7.7×10^{-6}
Palladium-107	0.0	0.0	0.0	0.0	0.0	0.0	2.4×10^{1}	0.0
Promethium-147	1.7×10^{3}	2.3×10^{2}	1.8×10^{4}	9.3×10^{4}	1.4×10^{4}	4.1×10^{-1}	0.0	2.2×10^{4}
Plutonium-238	2.2×10^{2}	2.9×10^{3}	1.8×10^{3}	5.3×10^{1}	1.3×10^{1}	2.1×10^{1}	4.8×10^{6}	8.6×10^{2}
Plutonium-239	1.3×10^{1}	3.8×10^{2}	4.9×10^{1}	2.9×10^{2}	5.7×10^{1}	1.6×10^{2}	4.8×10^{3}	2.1×10^{3}
Plutonium-240	7.6	2.7×10^{2}	4.0×10^{1}	1.1×10^{2}	2.3×10^{1}	6.0×10^{1}	5.6×10^{3}	1.9×10^{2}
Plutonium-241	1.1×10^{3}	7.1×10^{4}	1.1×10^{4}	4.9×10^{3}	1.0×10^{3}	3.3×10^{2}	1.6×10^{6}	1.7×10^{4}
Plutonium-242	1.9×10^{-2}	2.2	1.7×10^{-1}	1.2×10^{-2}	3.1×10^{-3}	6.6×10^{-3}	3.2×10^{1}	7.2×10^{-1}
Radium-226	6.8×10^{-3}	1.7×10^{-3}	7.8×10^{-8}	5.4×10^{-9}	3.0×10^{-9}	4.8×10^{-8}	2.2×10^{-3}	2.0×10^{-5}
Radium-228	2.2	3.5×10^{-1}	7.3×10^{-7}	1.0×10^{-5}	2.0×10^{-6}	7.2×10^{-6}	7.2×10^{-5}	3.1×10^{-4}
Rhodium-102	0.0	0.0	0.0	0.0	0.0	0.0	1.1×10^{1}	0.0
Ruthenium-106	1.8×10^{-2}	3.5×10^{-3}	1.4×10^{3}	4.0×10^{3}	6.4×10^{2}	9.7×10^{-11}	2.4×10^{6}	3.9×10^{1}
Selenium-79	1.7×10^{1}	2.9	4.5×10^{-1}	6.8×10^{-1}	1.3×10^{-1}	3.7×10^{-1}	1.4×10^{2}	1.6
Samarium-151	0.0	0.0	0.0	0.0	0.0	0.0	5.6×10^{5}	0.0
Tin-126	1.9×10^{1}	3.2	4.2×10^{-1}	6.3×10^{-1}	1.2×10^{-1}	3.5×10^{-1}	4.8×10^{2}	3.6
Strontium-90	8.9×10^{5}	1.4×10^{5}	7.5×10^{4}	1.3×10^{5}	2.3×10^{4}	2.5×10^{4}	1.8×10^{8}	1.9×10^{5}
Technetium-99	1.5×10^{2}	3.1×10^{1}	1.4×10^{1}	2.3×10^{1}	4.4	1.3×10^{1}	2.8×10^{4}	4.5×10^{1}
Thorium-229	2.2×10^{1}	4.9	5.1×10^{-6}	9.0×10^{-6}	2.7×10^{-6}	2.2×10^{-5}	3.8×10^{-3}	1.8×10^{-3}

Table G-14. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 25 through 30, 32, and 34 (continued).

			Uranium/zirconium hydride					
	Thorium/uranium oxide		Stainless steel/Incoloy clad		Aluminum clad			
Radionuclide	Zirconium clad Group 25	Stainless-steel clad Group 26	HEU Group 27	MEU Group 28	MEU Group 29	Declad Group 30	Naval spent nuclear fuel Group 32[a]	Miscellaneous Group 34
Thorium-230	4.9×10^{-1}	9.0×10^{-2}	1.6×10^{-5}	1.2×10^{-6}	4.1×10^{-7}	3.7×10^{-6}	7.2×10^{-1}	1.9×10^{-3}
Thorium-232	4.5	8.0×10^{-1}	8.5×10^{-7}	1.3×10^{-5}	2.4×10^{-6}	7.2×10^{-6}	9.2×10^{-5}	2.7×10^{-2}
Thallium-208	7.2×10^{3}	1.1×10^{3}	5.0×10^{-3}	8.7×10^{-4}	1.9×10^{-4}	3.4×10^{-4}	0.0	4.5×10^{-1}
Uranium-232	2.0×10^{4}	2.9×10^{3}	1.4×10^{-2}	2.5×10^{-3}	5.3×10^{-4}	9.1×10^{-4}	2.2×10^{2}	1.2
Uranium-233	1.4×10^{4}	2.5×10^{3}	2.4×10^{-3}	6.3×10^{-3}	1.3×10^{-3}	3.5×10^{-3}	1.2	8.7×10^{1}
Uranium-234	3.9×10^{2}	7.4×10^{1}	1.2×10^{-1}	8.7×10^{-3}	2.1×10^{-3}	8.1×10^{-3}	6.0×10^{3}	4.4
Uranium-235	3.0×10^{-2}	5.3×10^{-1}	2.1×10^{-1}	5.0×10^{-1}	1.3×10^{-1}	2.6×10^{-2}	1.2×10^{2}	2.1×10^{-1}
Uranium-236	6.3×10^{-2}	2.2×10^{-1}	4.7×10^{-1}	6.6×10^{-1}	1.3×10^{-1}	3.6×10^{-1}	1.0×10^{3}	1.3
Uranium-238	1.8×10^{-3}	1.1×10^{-1}	1.6×10^{-2}	3.9×10^{-1}	9.7×10^{-2}	1.5×10^{-2}	4.8×10^{-1}	8.6×10^{-2}
Zirconium-93	0.0	0.0	0.0	0.0	0.0	0.0	4.4×10^{3}	0.0

Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.
Note: There are no shipments of Group 31 and 33 spent nuclear fuel.
a. Radionuclide inventory is for 400 casks. Single cask naval spent fuel inventory is from DIRS 155857-McKenzie 2001, Table 3.
HEU = Highly enriched uranium.
LEU = Low-enriched uranium.
MEU= Medium-enriched uranium.

Table G-15. Radionuclide inventories (curies) for commercial spent nuclear fuel.

Radionuclide	BWR SNF inventory (Ci/assembly)[a]	BWR SNF total inventory[a]	PWR SNF inventory (Ci/assembly)[b]	PWR SNF total inventory[b]
Americium-241	3.73×10^{2}	4.84×10^{7}	1.28×10^{3}	1.21×10^{8}
Americium-242m	2.88	3.74×10^{5}	7.99	7.58×10^{5}
Americium-243	8.63	1.12×10^{6}	3.93×10^{1}	3.73×10^{6}
Carbon-14	1.69×10^{-1}	2.19×10^{4}	4.35×10^{-1}	4.13×10^{4}
Cadmium-113m	6.23	8.08×10^{5}	2.34×10^{1}	2.22×10^{6}
Cerium-144	1.73×10^{1}	2.24×10^{6}	6.99×10^{1}	6.63×10^{6}
Curium-242	2.38	3.09×10^{5}	6.60	6.26×10^{5}
Curium-243	5.55	7.20×10^{5}	2.48×10^{1}	2.35×10^{6}
Curium-244	9.23×10^{2}	1.20×10^{8}	5.85×10^{3}	5.55×10^{8}
Curium-245	9.07×10^{-2}	1.18×10^{4}	8.16×10^{-1}	7.74×10^{4}
Curium-246	4.26×10^{-2}	5.53×10^{3}	4.07×10^{-1}	3.86×10^{4}
Cobalt-60	1.14×10^{2}	1.48×10^{7}	2.17×10^{3}	2.06×10^{8}
Cobalt-60 (Crud)	5.66×10^{1}	7.34×10^{6}	1.69×10^{1}	1.60×10^{6}
Cesium-134	1.31×10^{3}	1.70×10^{8}	5.43×10^{3}	5.15×10^{8}
Cesium-137	2.41×10^{4}	3.13×10^{9}	7.16×10^{4}	6.79×10^{9}
Europium-154	7.79×10^{2}	1.01×10^{8}	3.01×10^{3}	2.85×10^{8}
Europium-155	1.93×10^{2}	2.51×10^{7}	6.42×10^{2}	6.09×10^{7}
Iron-55 (Crud)	9.84×10^{1}	1.28×10^{7}	2.09×10^{2}	1.98×10^{7}
Hydrogen-3	1.05×10^{2}	1.36×10^{7}	3.05×10^{2}	2.90×10^{7}
Iodine-129	9.22×10^{-3}	1.20×10^{3}	2.76×10^{-2}	2.62×10^{3}
Krypton-85	1.17×10^{3}	1.52×10^{8}	3.39×10^{3}	3.21×10^{8}
Neptunium-237	8.74×10^{-2}	1.13×10^{4}	2.94×10^{-1}	2.79×10^{4}
Promethium-147	2.11×10^{3}	2.74×10^{8}	6.06×10^{3}	5.75×10^{8}
Plutonium-238	1.02×10^{3}	1.32×10^{8}	3.98×10^{3}	3.77×10^{8}
Plutonium-239	5.41×10^{1}	7.02×10^{6}	1.75×10^{2}	1.66×10^{7}
Plutonium-240	1.27×10^{2}	1.65×10^{7}	3.63×10^{2}	3.44×10^{7}
Plutonium-241	1.57×10^{4}	2.04×10^{9}	5.64×10^{4}	5.35×10^{9}
Plutonium-242	7.08×10^{-1}	9.18×10^{4}	2.48	2.35×10^{5}
Ruthenium-106	9.05×10^{1}	1.17×10^{7}	4.04×10^{2}	3.83×10^{7}
Antimony-125	1.45×10^{2}	1.88×10^{7}	5.20×10^{2}	4.93×10^{7}
Strontium-90	1.66×10^{4}	2.15×10^{9}	4.51×10^{4}	4.28×10^{9}
Uranium-232	8.74×10^{-3}	1.13×10^{3}	3.61×10^{-2}	3.42×10^{3}
Uranium-234	2.39×10^{-1}	3.10×10^{4}	5.24×10^{-1}	4.97×10^{4}
Uranium-236	7.45×10^{-2}	9.66×10^{3}	1.77×10^{-1}	1.68×10^{4}
Uranium-238	6.24×10^{-2}	8.09×10^{3}	1.46×10^{-1}	1.38×10^{4}

Source: DIRS 169061-BSC 2004, all; DIRS 164364-BSC 2003, all.

a. Total inventory for pressurized water reactor spent nuclear fuel shipped in rail casks is based on 94,817 assemblies (calculated from rail and truck shipments and cask capacities from DIRS 181377-BSC 2007, Section 7).

b. Total inventory for boiling water reactor spent nuclear fuel shipped in rail casks is based on 129,721 assemblies (calculated from rail and truck shipments and cask capacities from DIRS 181377-BSC 2007, Section 7).

PWR = Pressurized-water reactor.
BWR = Boiling-water reactor.
SNF = Spent nuclear fuel.

Table G-16. Radionuclide inventories (curies) for high-level radioactive waste.

Radionuclide	Hanford Site[a]	Idaho National Laboratory[b]	Savannah River Site[c]	West Valley[d]
Actinium-227	7.38×10^{1}	0.0	0.0	1.03×10^{1}
Americium-241	1.08×10^{5}	5.87×10^{3}	1.17×10^{6}	5.84×10^{4}
Americium-242m	0.0	6.93×10^{-3}	2.72×10^{2}	3.15×10^{2}
Americium-243	1.13×10^{1}	6.42×10^{-3}	4.80×10^{3}	3.79×10^{2}
Carbon-14	0.0	1.28×10^{-2}	0.0	1.49×10^{2}
Cadmium-113m	7.76×10^{3}	0.0	9.17×10^{-8}	1.75×10^{3}
Cerium-144	0.0	0.0	1.34×10^{4}	3.39×10^{-3}
Californium-249	0.0	0.0	8.19×10^{1}	0.0
Californium-251	0.0	0.0	6.48×10^{1}	0.0
Curium-242	0.0	5.73×10^{-3}	0.0	2.60×10^{2}
Curium-243	8.28	2.17×10^{-4}	1.48×10^{3}	1.27×10^{2}
Curium-244	1.57×10^{2}	4.76×10^{-3}	1.53×10^{6}	6.62×10^{3}
Curium-245	0.0	1.71×10^{-6}	8.47×10^{1}	9.61×10^{-1}
Curium-246	0.0	4.00×10^{-8}	1.02×10^{2}	1.10×10^{-1}
Curium-247	0.0	1.43×10^{-14}	7.70×10^{1}	0.0
Curium-248	0.0	4.32×10^{-15}	0.0	0.0
Cobalt-60	1.87×10^{3}	1.48×10^{1}	6.51×10^{5}	3.81×10^{2}
Cesium-134	6.71×10^{2}	1.52×10^{-2}	6.83×10^{5}	7.49×10^{2}
Cesium-135	0.0	7.53×10^{1}	7.56×10^{2}	1.76×10^{2}
Cesium-137	2.80×10^{7}	2.75×10^{6}	1.94×10^{8}	6.86×10^{6}
Europium-152	7.76×10^{2}	0.0	0.0	2.93×10^{2}
Europium-154	5.03×10^{4}	2.76×10^{3}	1.47×10^{6}	6.45×10^{4}
Europium-155	1.82×10^{3}	3.49	2.38×10^{3}	1.12×10^{4}
Iron-55	0.0	0.0	0.0	1.55×10^{2}
Hydrogen-3	0.0	1.65×10^{3}	0.0	6.40×10^{1}
Iodine-129	3.61×10^{1}	2.61	1.13	2.29×10^{-1}
Niobium-93m	2.00×10^{3}	2.19×10^{2}	5.22×10^{2}	2.26×10^{2}
Niobium-94	0.0	2.48×10^{-3}	0.0	0.0
Nickel-59	1.03×10^{3}	0.0	2.95×10^{3}	1.16×10^{2}
Nickel-63	9.04×10^{4}	0.0	2.80×10^{5}	8.91×10^{3}
Neptunium-236	0.0	0.0	0.0	1.03×10^{1}
Neptunium-237	1.06×10^{2}	2.89	1.01×10^{2}	2.56×10^{1}
Protactinium-231	2.05×10^{2}	0.0	0.0	1.66×10^{1}
Palladium-107	0.0	0.0	4.59	1.20×10^{1}
Promethium-146	0.0	0.0	0.0	5.57
Promethium-147	0.0	1.23×10^{1}	7.77×10^{6}	1.96×10^{4}
Plutonium-236	0.0	0.0	0.0	9.20×10^{-1}
Plutonium-238	3.43×10^{3}	4.15×10^{4}	3.45×10^{6}	8.77×10^{3}
Plutonium-239	5.20×10^{4}	8.37×10^{2}	6.09×10^{4}	1.80×10^{3}
Plutonium-240	9.26×10^{3}	7.26×10^{2}	2.94×10^{4}	1.33×10^{3}
Plutonium-241	6.10×10^{4}	8.92×10^{3}	2.95×10^{6}	6.69×10^{4}
Plutonium-242	7.53×10^{-1}	1.58	7.49×10^{1}	1.80
Radium-226	6.78×10^{-2}	4.48×10^{-3}	0.0	0.0
Radium-228	1.58 × 101	0.0	0.0	1.72
Rhodium-102	0.0	9.20 × 10-6	0.0	0.0
Ruthenium-106	1.51	0.0	1.53 × 104	2.52 × 10-1
Antimony-125	1.86 × 103	4.76 × 10-1	4.20 × 105	1.77 × 103
Selenium-79	9.19 × 101	0.0	1.87 × 103	6.57 × 101

Table G-16. Radionuclide inventories (curies) for high-level radioactive waste (continued).

Radionuclide	Hanford Site[a]	Idaho National Laboratory[b]	Savannah River Site[c]	West Valley[d]
Samarium-151	2.46×10^6	0.0	5.64×10^5	8.78×10^4
Tin-121m	0.0	0.0	6.79×10^3	1.76×10^1
Tin-126	4.36×10^2	4.12×10^1	2.74×10^3	1.13×10^2
Strontium-90	3.07×10^7	3.25×10^6	1.20×10^8	6.34×10^6
Technetium-99	2.24×10^4	1.58×10^3	3.21×10^4	1.85×10^3
Thorium-228	0.0	0.0	0.0	9.40
Thorium-229	1.51	0.0	3.11×10^{-1}	2.35×10^{-1}
Thorium-230	0.0	1.83×10^{-1}	2.79×10^{-2}	6.40×10^{-2}
Thorium-232	6.02	4.57×10^{-8}	4.90	1.79
Uranium-232	3.01×10^1	2.14×10^{-3}	1.04	7.49
Uranium-233	3.84×10^2	6.15×10^{-4}	1.96×10^2	1.04×10^1
Uranium-234	1.66×10^2	4.60×10^1	1.58×10^2	5.03
Uranium-235	6.78	2.73×10^{-1}	2.32	1.10×10^{-1}
Uranium-236	4.52	7.12×10^{-1}	1.28×10^1	3.23×10^{-1}
Uranium-238	1.50×10^2	1.36×10^{-2}	1.66×10^2	9.32×10^{-1}
Zirconium-93	3.62×10^3	0.0	1.35×10^3	2.97×10^2

a. The Hanford Site high-level radioactive waste radionuclide inventory represents the radionuclide inventory in 5,325 canisters (DIRS 181377-BSC 2007, Section 7; based on radionuclide inventory from DIRS 184907-BSC 2008, Table 8).
b. The Idaho National Laboratory high-level radioactive waste radionuclide inventory represents the radionuclide inventory in 550 canisters (DIRS 181377-BSC 2007, Section 7; based on radionuclide inventory from DIRS 184907-BSC 2008, Table 17).
c. The Savannah River Site high-level radioactive waste radionuclide inventory represents the radionuclide inventory in 3,500 canisters (DIRS 181377-BSC 2007, Section 7; based on radionuclide inventory from DIRS 184907-BSC 2008, Table 3).
d. The West Valley high-level radioactive waste radionuclide inventory represents the radionuclide inventory in 300 canisters (DIRS 181377-BSC 2007, Section 7; based on radionuclide inventory from DIRS 184907-BSC 2008, Table 15).

inventory and thereby the radiation dose. The following descriptions are for typical spent nuclear fuel for each group listed in Tables G-11 through G-14.

Group 1: Uranium Metal, Zirconium Alloy Clad, Low-Enriched Uranium. This group contains uranium metal fuel compounds with zirconium alloy cladding. The end-of-life effective enrichment ranges from 0.5 to 1.7 percent. The cladding is in fair to poor condition. This group of fuel comprises approximately 2,103 MTHM.

Group 2: Uranium Metal, Non-Zirconium Alloy Clad, Low-Enriched Uranium. This group contains uranium metal fuel compounds with no known zirconium alloy cladding. The end-of-life effective enrichment ranges from 0.2 to 3.4 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 8 MTHM.

Group 3: Uranium-Zirconium. This group contains uranium-zirconium alloy fuel compounds with zirconium alloy cladding. The end-of-life effective enrichment ranges from 0.5 to 92.9 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.66 MTHM.

Group 4: Uranium-Molybdenum. This group contains uranium-molybdenum alloy fuel compounds with various types of cladding. The end-of-life effective enrichment ranges from 2.4 to 25.8 percent. If present, the cladding is in good to poor condition. This group of fuel comprises approximately 3.9 MTHM.

Group 5: Uranium Oxide, Intact Zirconium Alloy Clad, Highly Enriched Uranium. This group contains uranium oxide fuel compounds with intact zirconium alloy cladding. The end-of-life effective enrichment ranges from 23.1 to 92.5 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 1 MTHM.

Group 6: Uranium Oxide, Intact Zirconium Alloy Clad, Medium-Enriched Uranium. This group contains uranium oxide fuel compounds with intact zirconium alloy cladding. The end-of-life effective enrichment ranges from 5.0 to 6.9 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 1.9 MTHM.

Group 7: Uranium Oxide, Intact Zirconium Alloy Clad, Low-Enriched Uranium. This group contains uranium oxide fuel compounds with intact zirconium alloy cladding. The end-of-life effective enrichment ranges from 0.6 to 4.9 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 89.6 MTHM.

Group 8: Uranium Oxide, Intact Stainless-Steel/Hastelloy Clad, Highly Enriched Uranium. This group contains uranium oxide fuel compounds with intact stainless-steel or Hastelloy cladding. The end-of-life effective enrichment ranges from 91.0 to 93.2 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.19 MTHM.

Group 9: Uranium Oxide, Intact Stainless-Steel Clad, Medium-Enriched Uranium. This group contains uranium oxide fuel compounds with intact stainless-steel cladding. The end-of-life effective enrichment ranges from 5.5 to 20.0 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.69 MTHM.

Group 10: Uranium Oxide, Intact Stainless-Steel Clad, Low-Enriched Uranium. This group contains uranium oxide fuel compounds with stainless-steel cladding. The end-of-life effective enrichment ranges from 0.2 to 1.9 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.9 MTHM.

Group 11: Uranium Oxide, Non-Intact or Declad Non-Aluminum Clad, Highly Enriched Uranium. This group contains uranium oxide fuel compounds with no known aluminum cladding. The end-of-life effective enrichment ranges from 21.0 to 93.3 percent. If present, the cladding is in poor condition. This group of fuel comprises approximately 0.82 MTHM.

Group 12: Uranium Oxide, Non-Intact or Declad Non-Aluminum Clad, Medium-Enriched Uranium. This group contains uranium oxide fuel compounds with no known aluminum cladding. The end-of-life effective enrichment ranges from 5.2 to 18.6 percent. If present, the cladding is in poor condition. This group of fuel comprises approximately 0.47 MTHM.

Group 13: Uranium Oxide, Non-Intact or Declad Non-Aluminum Clad, Low-Enriched Uranium. This group contains uranium oxide fuel compounds with no known aluminum cladding. The end-of-life effective enrichment ranges from 1.1 to 3.2 percent. If present, the cladding is in poor condition. This group of fuel comprises approximately 82.5 MTHM.

Group 14: Uranium Oxide, Aluminum Clad, Highly Enriched Uranium. This group contains uranium oxide fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 58.1 to

89.9 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 4.6 MTHM.

Group 15: Uranium Oxide, Aluminum Clad, Medium-Enriched Uranium and Low-Enriched Uranium. This group contains uranium oxide fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 8.9 to 20.0 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.29 MTHM.

Group 16: Uranium-Aluminum, Highly Enriched Uranium. This group contains uranium-aluminum alloy fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 21.9 to 93.3 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 7.5 MTHM.

Group 17: Uranium-Aluminum, Medium-Enriched Uranium. This group contains uranium-aluminum alloy fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 9.0 to 20.0 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 2.6 MTHM.

Group 18: Uranium-Silicide. This group contains uranium-silicide fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 5.2 to 22.0 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 7.2 MTHM.

Group 19: Thorium/Uranium Carbide, TRISO- or BISO-Coated Particles in Graphite. This group contains thorium/uranium carbide fuel compounds with TRISO (tristructural isotopic)- or BISO (bistructural isotopic)-coated particles. TRISO-coated particles consist of an isotropic pyrocarbon outer layer, a silicon carbide layer, an isotropic carbon layer, and a porous carbon buffer inner layer. BISO-coated particles consist of an isotropic pyrocarbon outer layer and a low-density, porous carbon buffer inner layer. The end-of-life effective enrichment ranges from 71.4 to 84.4 percent. The coating is in good condition. This group of fuel comprises approximately 24.7 MTHM.

Group 20: Thorium/Uranium Carbide, Mono-Pyrolytic Carbon-Coated Particles in Graphite. This group contains thorium/uranium carbide fuel compounds with mono-pyrolytic carbon-coated particles. The end-of-life effective enrichment ranges from 80.6 to 93.2 percent. The coating is in poor condition. This group of fuel comprises approximately 1.6 MTHM.

Group 21: Plutonium/Uranium Carbide, Nongraphite Clad, Not Sodium Bonded. This group contains plutonium/uranium carbide fuel compounds with stainless-steel cladding. The end-of-life effective enrichment ranges from 1.0 to 67.3 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 0.08 MTHM.

Group 22: Mixed Oxide, Zirconium Alloy Clad. This group contains plutonium/uranium oxide fuel compounds with zirconium alloy cladding. The end-of-life effective enrichment ranges from 1.3 to 21.3 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 1.6 MTHM.

Group 23: Mixed Oxide, Stainless-Steel Clad. This group contains plutonium/uranium and plutonium oxide fuel compounds with stainless-steel cladding. The end-of-life effective enrichment ranges from

2.1 to 87.4 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 10.7 MTHM.

Group 24: Mixed Oxide, Non-Stainless-Steel/Non-Zirconium Alloy Clad. This group contains plutonium/uranium oxide fuel compounds with no known stainless-steel or zirconium alloy cladding. The end-of-life effective enrichment ranges from 5.0 to 54.3 percent. The cladding is in poor to nonintact condition. This group of fuel comprises approximately 0.11 MTHM.

Group 25: Thorium/Uranium Oxide, Zirconium Alloy Clad. This group contains thorium/uranium oxide fuel compounds with zirconium alloy cladding. The end-of-life effective enrichment ranges from 10.1 to 98.4 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 42.6 MTHM.

Group 26: Thorium/Uranium Oxide, Stainless-Steel Clad. This group contains thorium/uranium oxide fuel compounds with stainless-steel cladding. The end-of-life effective enrichment ranges from 7.6 to 97.8 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 7.6 MTHM.

Group 27: Uranium-Zirconium Hydride, Stainless-Steel/Incoloy Clad, Highly Enriched Uranium. This group contains uranium-zirconium hydride fuel compounds with stainless-steel or Incoloy cladding. The end-of-life effective enrichment ranges from 42.5 to 93.2 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.16 MTHM.

Group 28: Uranium-Zirconium Hydride, Stainless-Steel/Incoloy Clad, Medium-Enriched Uranium. This group contains uranium-zirconium hydride fuel compounds with stainless-steel or Incoloy cladding. The end-of-life effective enrichment ranges from 11.9 to 20.0 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 1.4 MTHM.

Group 29: Uranium-Zirconium Hydride, Aluminum Clad, Medium-Enriched Uranium. This group contains uranium-zirconium hydride fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 16.8 to 20.0 percent. The cladding is in good condition. This group of fuel comprises approximately 0.35 MTHM.

Group 30: Uranium-Zirconium Hydride, Declad. This group contains uranium-zirconium hydride fuel compounds that have been declad. The end-of-life effective enrichment is about 89.7 percent. This group of fuel comprises approximately 0.03 MTHM.

Group 31: Metallic Sodium Bonded. This group contains a wide variety of spent nuclear fuel that has the common attribute of containing metallic sodium bonding between the fuel matrix and the cladding. The end-of-life effective enrichment ranges from 0.1 to 93.2 percent. If present, the cladding is in good to poor condition. This group of fuel comprises approximately 59.9 MTHM. This spent nuclear fuel will be treated and disposed of as high-level radioactive waste.

Group 32: Naval Fuel. Naval nuclear fuel is highly robust and designed to operate in a high-temperature, high-pressure environment for many years. This fuel is highly enriched (93 to 97 percent) in uranium-235. In addition, to ensure that the design will be capable of withstanding battle shock loads, the naval fuel material is surrounded by large amounts of zirconium alloy. This group of fuel comprises approximately 65 MTHM.

Group 33: Canyon Stabilization. This spent nuclear fuel is being treated and will be disposed of as high-level radioactive waste.

Group 34: Miscellaneous. This group contains spent nuclear fuel that does not fit into other groups. The spent nuclear fuel in this group was generated from numerous reactors of different types. The end-of-life effective enrichment ranges from 14.6 to 90.0 percent. If present, the cladding is in good to poor condition. This group of fuel comprises of approximately 0.44 MTHM.

For DOE spent nuclear fuel, 752 canisters from the Hanford Site, 1,603 canisters from the Idaho National Laboratory, 400 canisters from the Savannah River Site, and 400 canisters of naval spent nuclear fuel would be shipped (DIRS 181377-BSC 2007, Section 7). The DOE spent nuclear fuel radionuclide inventories are for the amount of spent nuclear fuel that DOE would ship in rail casks. The radionuclide inventories for DOE spent nuclear fuel were compiled from data in *Source Term Estimates for DOE Spent Nuclear Fuels* (DIRS 169354-DOE 2004, Volume II, Appendix C). For naval spent nuclear fuel, the radionuclide inventory is for 400 casks containing 400 canisters. The single cask naval spent fuel inventory was compiled the U.S. Department of the Navy (DIRS 155857-McKenzie 2001, Table 3). Tables G-11 through G-14 list the radionuclide inventories for DOE spent nuclear fuel.

For commercial spent nuclear fuel, the radionuclide inventories are for the amount of spent nuclear fuel that DOE would ship in rail and truck casks. For pressurized-water-reactor spent nuclear fuel, DOE would ship an estimated 93,671 spent nuclear fuel assemblies in rail and truck casks (DIRS 181377-BSC 2007, Section 7). For boiling-water-reactor spent nuclear fuel, the Department would ship 128,105 spent nuclear fuel assemblies in rail and truck casks (DIRS 181377-BSC 2007, Section 7). This analysis assumed that all transportation casks would be full and all trains would have a full complement of casks. This increases the number of spent nuclear fuel assemblies to 94,817 for pressurized-water-reactor spent nuclear fuel and 129,721 for boiling-water-reactor spent nuclear fuel. The representative pressurized-water-reactor assembly would have a burnup of 60,000 megawatt-days per MTHM, an enrichment of 4 percent, and a decay time of 10 years (DIRS 169061-BSC 2004, all). The representative boiling-water-reactor assembly would have a burnup of 50,000 megawatt-days per MTHM, an enrichment of 4 percent, and a decay time of 10 years (DIRS 164364-BSC 2003, all). Table G-15 lists the radionuclide inventory for commercial spent nuclear fuel.

The high-level radioactive waste radionuclide inventory is based on 5,316 canisters from the Hanford Site, 528 canisters from the Idaho National Laboratory, 3,490 canisters from the Savannah River Site, and 277 canisters from West Valley (DIRS 181377-BSC 2007, Section 7). This radionuclide inventory is based on the recommended values from *Recommended Values for HLW Glass for Consistent Usage on the Yucca Mountain Project* (DIRS 184907-BSC 2008, Tables 8, 17, 3, 15) and represents the average radionuclide inventory in a canister at the Hanford Site, the Idaho National Laboratory, and West Valley. For the Savannah River Site, the radionuclide inventory represents the maximum radiological loading for future production (DIRS 184970-BSC 2008, p. 15). This analysis assumed that all transportation casks that contained high-level radioactive waste would be full and all trains would have a full complement of casks. This increases the amount of high-level radioactive waste to 5,325 canisters for Hanford Site, 550 canisters for Idaho National Laboratory, 3,500 canisters for Savannah River Site, and 300 canisters from

West Valley and also increases the total radionuclide inventory to that which would be present in these numbers of canisters. Table G-16 lists the radionuclide inventory for high-level radioactive waste.

G.5 Incident-Free Transportation

The impacts from incident-free transportation can be related to either the cargo being carried or to the vehicle that carries the cargo. Incident-free impacts that are related to the cargo are known as radiological impacts. Incident-free impacts that are related to the vehicle are nonradiological in nature and are known as vehicle emission impacts.

G.5.1 RADIOLOGICAL IMPACTS

Radiation doses during normal, incident-free transportation of radioactive materials result from exposure of workers and the public to the external radiation field that surrounds the shipping containers. The radiation dose is a function of the number of people exposed, their proximity to the containers, their length of time of exposure, and the intensity of the radiation field.

In most cases, rail casks would be shipped to the repository using dedicated trains. A dedicated train would consist only of equipment and lading associated with the transportation of spent nuclear fuel and high-level radioactive waste; that is, the train would consist only of necessary motive power, buffer cars, and cask cars, together with a car for escort personnel. Such a train would not transport other rail rolling stock, other revenue, or company freight. For shipments of commercial spent nuclear fuel, there would be three casks that contained spent nuclear fuel per train. For shipments of DOE spent nuclear fuel and high-level radioactive waste, there would be five casks per train. Other numbers of casks per train could be possible for shipments of commercial spent nuclear fuel and DOE spent nuclear fuel and high-level radioactive waste. In both cases, two buffer railcars, two locomotives, and one escort railcar would be in the train. Escorts would be present in all areas (rural, suburban, and urban) for all rail shipments.

Truck casks would be shipped to the repository on overweight trucks. Escorts would be present in all areas (rural, suburban, and urban) for all truck shipments.

DOE determined radiological impacts for members of the public and workers during normal, incident-free transportation of the casks. For members of the public, the Department estimated radiation doses for:

- People within 800 meters (0.5 mile) of the transportation route. The doses to these people are referred to as off-link radiation doses.

- People in vehicles sharing the transportation route. The doses to these people are referred to as on-link radiation doses.

- People exposed at stops that occur en route to the repository. For truck transportation, these would include stops for refueling, food, and rest, and for brief inspections at regular intervals. For rail transportation, stops would occur in rail yards at the beginning of the trip, at the Staging Yard at the end of the trip, and along the route to change crews and equipment. Stops would also include the intermodal transfers of rail casks for shipments from generator sites without direct rail access.

- Workers such as truck drivers, escorts, inspectors, and workers at rail yards or at the Staging Yard at the end of the trip. Engineers and conductors would be in the train locomotives at least 46 meters (150 feet) from the closest rail cask, shielded from radiation exposure by the locomotives; therefore, there would be no radiation doses for these workers en route to the repository. Workers would also be exposed during Commercial Vehicle Safety Alliance truck inspections at the beginning and end of a shipment and during intermodal transfers of rail casks for shipments from generator sites without direct rail access.

G.5.1.1 Collective Radiation Dose Scenarios

Radiation doses received by a population of workers or members of the public are referred to as collective radiation doses. DOE estimated collective radiation doses based on unit risk factors. Unit risk factors provide an estimate of the radiation doses from transport of one shipment or container of radioactive material over a unit distance of travel in a given population density zone.

Unit risk factors can provide an estimate of the radiation dose from one container or shipment being stopped at a location such as a rail yard or the radiation dose from one container or shipment passing a train stopped at a siding. DOE used five types of unit risk factors to estimate collective incident-free radiation doses:

- Unit risk factors to estimate incident-free radiation doses that depended on the number of casks, the population density in each population zone, and the distance in each population zone;

- Unit risk factors to estimate incident-free radiation doses that depended on the number of casks and the distance in each population zone;

- Unit risk factors to estimate incident-free radiation doses that depended on the number of casks and the population density around locations such as a rail yard;

- Unit risk factors to estimate incident-free radiation doses that depended on the number of trains (that is, shipments) and the distance in each population zone; and

- Unit risk factors to estimate incident-free radiation doses that depended on the number of casks.

The Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. J-40) contains a more detailed explanation of how DOE used unit risk factors to estimate radiation doses. As in the FEIS (DIRS 155970-DOE 2002, Section J.1.3.2), DOE estimated the unit risk factors using the RADTRAN 5 computer program (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser et al. 2000, all) and the RISKIND computer program (DIRS 101483-Yuan et al. 1995, all). Both RADTRAN and RISKIND have been verified and validated for estimating incident-free radiation doses during transportation of radioactive material (DIRS 101845-Maheras and Pippen 1995, all; DIRS 177031-Osborn et al. 2005, all; DIRS 102060-Biwer et al. 1997, all).

The incident-free unit risk factors used in the analysis in this Repository SEIS are similar to those in the Yucca Mountain FEIS (DIRS 157144-Jason Technologies 2001, Tables 4-20 and 4-21) with the following changes:

- The dedicated train exposure factors are used to estimate worker and public exposures during stops at rail yards. One stop would occur at the rail yard closest to the generator site and another at the Staging Yard in Nevada. A stop time of 2 hours was used for these stops. Two-hour stops would also occur every 277 kilometers (170 miles). For shipments using regular freight trains, a 30-hour stop was used to estimate worker and public exposures.

- Escorts would be present in the escort car from the time the train was assembled at the generator site until it reached its final destination at the repository.

- For generator sites without direct rail access, four escort cars would accompany the heavy-haul truck carrying the rail cask. At the point where the rail cask was moved from the heavy-haul truck to the railcar, assembly of the dedicated train would take 30 hours. The escorts would be present for this 30-hour period.

- A train containing commercial spent nuclear fuel would contain three casks. A train containing DOE spent nuclear fuel and high-level radioactive waste would contain five casks. The escorts would be exposed only to radiation from by the cask closest to the escort car. The shielding of this car would effectively shield the escorts from the other casks in the train.

- Unit risk factors were estimated for workers at the Maintenance-of-Way Facility, workers at sidings, and noninvolved workers at the Staging Yard; the Yucca Mountain FEIS did not address these facilities and activities. These unit risk factors are discussed in Appendix K of the Rail Alignment EIS.

As in the Yucca Mountain FEIS, DOE set the external dose rates for the truck and rail casks at their regulatory maximum, 10 millirem per hour at 2 meters (6.6 feet) from the truck trailer or railcar.

G.5.1.2 Maximally Exposed Individual Dose Scenarios

Maximally exposed individuals are hypothetical workers and members of the public who would receive the highest radiation doses. The scenarios DOE used to estimate the radiation doses are similar to the scenarios in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Section J.1.3.2.2) and were evaluated on the national level and on the Nevada level. National scenarios incorporate conditions such as speeds, distances, and exposure times that would be representative of exposures across the United States. Nevada scenarios incorporate site-specific conditions for exposures in Nevada.

G.5.1.2.1 *National Scenarios*

For workers, DOE evaluated the following scenarios:

- An escort 27 meters (90 feet) from the rail cask. This person would be exposed for 2,000 hours per year. The 27-meter distance includes the length of the buffer railcar between the last rail cask car and the escort car.

- An inspector 1 meter (3.3 feet) from the rail or truck cask for 1 hour per cask (DIRS 155970-DOE 2002, p. J-42). This person's radiation dose was based on a working year of 2,000 hours, which results in the person's exposure to 23 percent of the rail or truck casks.

- A truck driver who would drive shipments that contained loaded casks for 1,000 hours per year and unload casks for 1,000 hours per year.

- A rail yard crew member 10 meters (33 feet) from the rail cask for 2 hours per cask (DIRS 155970-DOE 2002, p. J-42). This person's radiation dose was based on a working year of 2,000 hours, which results in the person's exposure to 23 percent of the rail casks.

For members of the public, DOE evaluated the following scenarios:

- Typically, there is an 18-meter (60-foot) buffer zone around rail lines that is railroad property, within which people cannot build homes. Therefore, DOE estimated the radiation dose to a resident living 18 meters from a rail line. This individual was assumed to be exposed to all loaded rail casks as they passed by en route to the repository.

- A resident 200 meters (660 feet) from a rail yard (DIRS 155970-DOE 2002, p. J-42). This person would be exposed for 2 hours per cask (DIRS 180923-Nevada Rail Partners 2007, p. 7-1).

- A person stuck in a traffic jam next to the cask for 1 hour. The person would be 1.2 meters (4 feet) from the cask (DIRS 155970-DOE 2002, p. J-42).

- A resident 30 meters (100 feet) from a road or highway. This individual would be exposed to all loaded truck casks as they passed by en route to the repository (DIRS 155970-DOE 2002, p. J-42).

- A person at a service station. This person would be exposed for 49 minutes to each truck cask at a distance of 16 meters (52 feet) (DIRS 155970-DOE 2002, p. J-42).

G.5.1.2.2 *Nevada Scenarios*

For workers, DOE evaluated the following scenarios:

- An escort 27 meters (90 feet) from the rail cask. This person would be exposed for 2,000 hours per year. The 27-meter distance includes the length of the buffer railcar between the last rail cask car and the escort car.

- An inspector 1 meter (3.3 feet) from the rail or truck cask for 1 hour per cask. This person's radiation dose was based on a working year of 2,000 hours, which results in the person's exposure to 23 percent of the rail or truck casks.

- A rail yard crew member 10 meters (33 feet) from the rail cask for 2 hours per cask. This person's radiation dose was based on a working year of 2,000 hours, which results in the person's exposure to 23 percent of the rail or truck casks.

For workers, two scenarios that were not addressed in the Yucca Mountain FEIS have been added to the analysis for this Repository SEIS:

- In the first scenario, a worker at the Maintenance-of-Way Facility would be exposed to a loaded cask train traveling 50 kilometers (31 miles) per hour as it passed the facility en route to the repository. This worker would be 60 meters (200 feet) from the cask as it passed.

- In the second scenario, a worker at a siding would be exposed to a loaded rail cask train traveling 50 kilometers (31 miles) per hour as it passed the siding en route to the repository. This worker would be 7.6 meters (25 feet) from the rail cask as it passed.

A separate truck driver scenario was not evaluated in Nevada because the exposure of the driver was based on travel from generator sites to the repository, and there would be no drivers who drove solely in Nevada.

For members of the public, the following scenarios were evaluated:

- Typically, there is an 18-meter (60-foot) buffer zone around rail lines that is railroad property and within which people cannot build homes. Therefore, DOE estimated the radiation dose to a resident living 18 meters from a rail line. This individual was assumed to be exposed to all loaded rail casks as they passed by en route to the repository.

- In some cases, individuals could have access to locations that are closer than 18 meters (60 feet) from a rail line. For example, Nevada Agency for Nuclear Projects (DIRS 158452-Nevada Agency for Nuclear Projects 2002, p. 123) states that in the Las Vegas area, individuals could be 15, 20, 30, 35, 40, 100, and 160 meters (49, 66, 98, 110, 130, 330, and 520 feet) from the rail line. In the area of the Reno Trench, an individual could be as close as 5 meters (16 feet) from the rail line. Therefore, radiation doses were estimated for individuals at these distances from the rail line. These locations were not permanently occupied by residents. However, to provide a conservative estimate of potential impacts, they were assumed to be exposed to all loaded casks that passed through Las Vegas or Reno en route to the repository.

- In Nevada, Interstate Highway 15, the Las Vegas beltway, and U.S. Highway 95 would be used for truck shipments. There are typically buffer zones along interstate highways and beltways so people cannot build homes much closer than about 30 meters (100 feet) from the road. However, U.S. Highway 95 passes through Indian Springs on the way to the repository. In Indian Springs, an individual could reside as close as 24 meters (80 feet) from the highway. Therefore, the radiation dose was estimated for an individual who resided at this location and who was exposed to all loaded truck casks as they passed by en route to the repository.

- A person stuck in a traffic jam next to the cask for 1 hour. The person would be 1.2 meters (4 feet) from the cask.

- A person at a service station. This person would be exposed for 49 minutes to each truck cask at a distance of 16 meters (52 feet) (DIRS 155970-DOE 2002, p. J-42).

- A resident living near the staging yard would be exposed to all loaded casks at the yard for a duration of 2 hours per cask (DIRS 180923-Nevada Rail Partners 2007, p. 7-1). Table G-17 lists the distances from the staging yard for these residents, which were based on site-specific data around each yard.

Table G-17. Distances to members of the public around staging yards.

Staging yard location	Distance (meters)	Distance (feet)	Type of location
Caliente-Indian Cove	1,600	5,250	Residence
Caliente-Upland	400	1,310	Residence
Eccles-North	1,500	4,920	Residence
Mina-Hawthorne	660	2,170	Business

G.5.2 VEHICLE EMISSION IMPACTS

The analysis estimated incident-free impacts from vehicle emissions using unit risk factors that account for fatalities associated with emissions of exhaust and fugitive dust in urban, suburban, and rural areas by transportation vehicles, including escort vehicles. Because the impacts would occur equally for trucks and railcars transporting loaded or unloaded transportation casks, the analysis used round-trip distances. Because escorts were present in all areas, escort vehicle emission impacts were also estimated based on round trips.

For trucks, the vehicle emission unit risk factor was 1.5×10^{-11} fatalities per kilometer per person per square kilometer (9.3×10^{-12} fatalities per mile per person per square mile) (DIRS 157144-Jason Technologies 2001, p. 98). For escort vehicles, the vehicle emission unit risk factor was 9.4×10^{-12} fatalities per kilometer per person per square kilometer (5.8×10^{-12} fatalities per mile per person per square mile) (DIRS 157144-Jason Technologies 2001, p. 99). For railcars, the vehicle emission unit risk factor was 2.6×10^{-11} fatalities per kilometer per person per square kilometer (1.6×10^{-11} fatalities per mile per person per square mile) (DIRS 157144-Jason Technologies 2001, p. 99).

G.6 Transportation Accident Risks

Transportation accident risks can be related either to the cargo being carried or to the vehicle that carries the cargo. Transportation accident risks that are related to the cargo are known as radiological accident risks. Transportation accident risks that are related to the vehicle are nonradiological in nature and are known as transportation accident fatalities.

G.6.1 TRANSPORTATION RADIOLOGICAL ACCIDENT RISKS

The radiological dose risks from transporting spent nuclear fuel and high-level radioactive waste would result from (1) accidents in which there was no breach of the containment and no loss of shielding, (2) accidents in which there was no breach of the containment provided by the transportation cask, but there was loss of shielding because of lead shield displacement and (3) accidents that released and dispersed radioactive material from the transportation cask. In this Repository SEIS, the risk to the general public from the radiological consequences of transportation accidents is called dose risk. Dose risk is the sum of the products of the probabilities (dimensionless) and the consequences (in person-rem) of all potential transportation accidents. The probability of a single accident is usually determined by historical information on accidents of a similar type and severity. The consequences are estimated by analysis of the quantity of radionuclides likely to be released, potential exposure pathways, potentially affected population, likely weather conditions, and other information.

Potential accidents range from accidents with higher probabilities and lower consequences to accidents with lower probabilities and higher consequences. The analysis used the following information to determine the risks of accidents:

- The number of shipments;
- The distances and population densities along the transportation routes in rural, suburban, and urban areas;
- The kind and amount of radioactive material that would be transported;
- Transportation accident rates;
- Conditional probabilities of release and the fraction of cask contents that could be released in accidents;
- Conditional probabilities of amounts of lead shielding displacement that could occur during accidents and the resulting radiation dose rates; and
- Exposure scenarios including inhalation, ingestion, groundshine, resuspension, and immersion pathways, state-specific agricultural factors, and neutral (or average) atmospheric dispersion factors.

As in the incident-free transportation analysis, DOE used the RADTRAN 5 computer program (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser et al. 2000, all) to estimate unit risk factors for accidents that involved loss of shielding or when the shielding was undamaged. RADTRAN 5 was also used to estimate unit risk factors for accidents that involved the release of radioactive material from the cask for each radionuclide of concern in spent nuclear fuel and high-level radioactive waste. RADTRAN has been verified and validated for estimating the accident risks from transport of radioactive material (DIRS 101845-Maheras and Pippen 1995, all; DIRS 177031-Osborn et al. 2005, all). The unit risk factors were combined with radionuclide inventories, number of shipments, accident rates, conditional probabilities of release, release fractions, distance, and population densities to determine the dose risk for populations within 80 kilometers (50 miles) of the rail alignment.

The methods and data DOE used to estimate the dose risks were the same as those in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Section J.1.4.2) with the following exceptions:

- The distances and population densities have been updated,
- The number of rail casks to be shipped has been updated,
- Track Class-specific rail accident rates were used in the analysis,
- Truck accident rates have been updated,
- The radionuclide inventories have been updated through additional data collection and analysis,
- Updated radiation dosimetry has been used to estimate unit risk factors and radiation doses, and

- Updated health risk conversion factors have been used to estimate the number of latent cancer fatalities.

TRACK CLASS

The Federal Railroad Administration's Track Safety Standards, at 49 CFR Part 213, establish track structure and track geometry requirements for nine separate classes of track (Sections 213.9 and 213.307) with designated maximum speeds for each class. Railroads indicate the class to which each track belongs. Once the designation is made, the railroads are held responsible for maintaining each track to specified tolerances for its designated class. A railroad becomes liable for civil penalties if it fails to maintain a track to proper standards or if it operates trains at speeds in excess of the limits of the designated class.

- The lowest class is referred to as excepted track. Only freight trains are allowed to operate on this type of track, and they may run at speeds up to 10 miles per hour.
- Class 1 track is the lowest class allowing the operation of passenger trains. Freight train speeds are still limited to 10 miles per hour, and passenger trains are restricted to 15 miles per hour.
- Class 2 track limits freight trains to 25 miles per hour and passenger trains to 30 miles per hour.
- Class 3 track limits freight trains to 40 miles per hour and passenger trains to 60 miles per hour.
- Class 4 track limits freight trains to 60 miles per hour and passenger trains to 80 miles per hour. Most through lines, especially owned by the major Class 1 railroads (BNSF, CSX, Norfolk Southern, and Union Pacific), are Class 4 track.
- Class 5 track limits freight trains to 80 miles per hour and passenger trains to 90 miles per hour. The most significant portion of Class 5 track is in the western part of the Union Pacific mainlines, but the top speed on these lines is limited to 70 miles per hour.

In the United States, the regulations for Track Classes 6 through 9 are designed for passenger trains. Any freight cars moved at passenger speeds must meet the dynamic performance standards of passenger equipment. The only such track is Amtrak passenger lines in the Northeast Corridor.

- Class 6 limits freight trains and passenger trains to 110 miles per hour.
- Class 7 limits freight trains and passenger trains to 125 miles per hour. Most of Amtrak's Northeast Corridor is Class 7 track.
- Class 8 limits freight trains and passenger trains to 160 miles per hour. A few small lengths of Amtrak's Northeast Corridor are Class 8 track.
- Class 9 limits freight trains and passenger trains to 200 miles per hour. There is currently no Class 9 track in the United States.

G.6.1.1 Transportation Accident and Fatality Rates

In the Yucca Mountain FEIS, DOE used rail accident rates from the *State-Level Accident Rates of Surface Freight Transportation: A Reexamination* (DIRS 103455-Saricks and Tompkins 1999, all) to estimate radiological transportation risks. These rates were in terms of accidents per railcar kilometers and were based on 68-railcar trains. Because DOE has adopted a policy of using dedicated trains that would contain 8 to 10 cars on average for shipments of commercial spent nuclear fuel and for most DOE spent nuclear fuel and high-level radioactive waste in this Repository SEIS, a combination of rail accident rates based on both train kilometers and railcar kilometers was used to estimate accident risks (Table G-18).

Table G-18. Track Class 3 rail accident rates.

Train-based accident rate		Railcar-based accident rate	
(accidents per train kilometer)	(accidents per train mile)	(accidents per railcar kilometer)	(accidents per railcar mile)
7.5×10^{-7}	1.2×10^{-6}	1.7×10^{-8}	2.7×10^{-8}

Source: DIRS 180220-Bendixen and Facanha 2007, all.

These rates were for Track Class 3 and include derailments and collisions (DIRS 180220-Bendixen and Facanha 2007, all). DOE updated rail fatality rates to reflect data from 2000 to 2004 (DIRS 178016-DOT 2005, all). These fatality rates were in terms of fatalities per railcar kilometer.

In the Yucca Mountain FEIS, DOE used state-specific accident and fatality rate data for 1994 to 1996 (DIRS 103455-Saricks and Tompkins 1999, all) to estimate transportation impacts. For trucks, the Department obtained accident and fatality rate data it used in the FEIS from the U.S. Department of Transportation's Federal Motor Carrier Safety Administration, Motor Carrier Management Information System. Since completion of the FEIS, the Federal Motor Carrier Safety Administration has evaluated the data in the Information System. For 1994 through 1996, it found that accidents were underreported by about 39 percent and fatalities were underreported by about 36 percent (DIRS 181755-UMTRI 2003, Table 1, p. 4, and Table 2, p. 6). Therefore, in this Repository SEIS, DOE increased the state-specific truck accident and fatality rates from Saricks and Tompkins by factors of 1.64 and 1.57, respectively, to account for the underreporting.

G.6.1.2 Conditional Probabilities and Release Fractions

In this Repository SEIS, DOE spent nuclear fuel is organized into 34 groups based on the fuel compound, fuel matrix, fuel enrichment, fuel cladding material, and fuel cladding condition. Commercial spent nuclear fuel is organized into two groups, pressurized-water reactor and boiling-water reactor spent nuclear fuel. High-level radioactive waste is organized into four groups: that from Idaho National Laboratory, Hanford Site, Savannah River Site, and West Valley. These groups were assigned to a set of 10 conditional probabilities and release fractions known as release fraction groups based on the characteristics and behavior of the spent nuclear fuel or high-level radioactive waste (DIRS 157144-Jason Technologies 2001, Tables 5-24 to 5-27, 5-33, 5-35, 5-39, 5-41, 5-43, 5-45, 5-46, and 5-48). Release fractions were specified for inert gases, volatile constituents such as cesium and ruthenium, particulates, and activation products such as cobalt-60 that were deposited on the exterior surfaces of the spent nuclear fuel (also known as crud).

For loss-of-shielding accidents, the Yucca Mountain FEIS lists unit risk factors for six severity categories (DIRS 155970-DOE 2002, p. J-54, Table J-19). These unit risk factors are used in this analysis.

G.6.1.3 Atmospheric Conditions

Atmospheric conditions would affect the dispersion of radionuclides that could be released from an accident. Because it is not possible to forecast the atmospheric conditions that might exist during an accident, DOE selected neutral weather conditions (Pasquill Stability Class D) for the transportation risk assessments for the Yucca Mountain FEIS and for this Repository SEIS. Neutral weather conditions are typified by moderate wind speeds, vertical mixing in the atmosphere, and good dispersion of atmospheric contaminants. On the basis of observations from National Weather Service surface meteorological stations at 177 locations in the United States, on an annual average, neutral conditions (Pasquill Class C and D) occur 11 percent and 47 percent of the time, respectively. Stable conditions (Pasquill Class E and F) occur 12 percent and 21 percent of the time, respectively. Unstable conditions (Pasquill Class A and B) occur 1 percent and 7 percent of the time, respectively (DIRS 104800-CRWMS M&O 1999, p. 40).

G.6.1.4 Population Density Zones

DOE used three population density zones (urban, rural, and suburban) for the transportation risk assessment. Urban areas were defined as areas with a population density greater than 1,284 people per square kilometer (3,326 people per square mile). Rural areas were defined as areas with a population density less than 54 people per square kilometer (139 people per square mile). Suburban areas were areas with a population density between 54 and 1,284 people per square kilometer. The actual population densities were based on 2000 Census data. In Las Vegas, the population density was modified to include casino guests and casino workers, based on data from the Nevada Agency for Nuclear Projects (DIRS 158452-Nevada Agency for Nuclear Projects 2002, Table 3.8.12). The population densities and radiological impacts were escalated to 2067 using the escalation factors in Table G-9.

G.6.1.5 Exposure Pathways

DOE estimated radiological doses for an individual near the scene of the accident and for populations within 80 kilometers (50 miles) of the accident. Dose calculations considered a variety of exposure pathways, including inhalation and direct exposure (immersion or cloudshine) from the passing cloud, ingestion of contaminated food, direct exposure (groundshine) from radioactivity deposited on the ground, and inhalation of resuspended radioactive particles from the ground (resuspension).

G.6.1.6 Unit Risk Factors and Radiation Dosimetry

As discussed in Section G.6.1, DOE estimated the radiation doses from transportation accidents using unit risk factors. Unit risk factors were estimated using the RADTRAN 5 computer program (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser et al. 2000, all) for five pathways: (1) ingestion, (2) inhalation, (3) immersion, (4) resuspension, and (5) groundshine. For transportation accidents, unit risk factors provide estimates of:

- The radiation dose to an average person in a surrounding unit area (for example, a population density of one person per square kilometer) that could result if 1 curie of a specified radionuclide were released.
- The dose to a general population from ingestion of contaminated food from the accidental release of 1 curie of a specified radionuclide. The unit risk factor includes the assumption that all contaminated food is consumed.
- For transportation accidents in which a portion of a cask's radiation shield was damaged or lost (loss-of-shielding accidents), and for cases in which the cask’s shield could remain intact, unit risk factors provide estimates of the resulting radiation dose to a person in a surrounding unit area after an accident.

DOE used the inhalation and ingestion dose coefficients from *The ICRP Database of Dose Coefficients: Workers and Members of the Public* (DIRS 172935-ICRP 2001, all) and the groundshine and immersion dose coefficients from *Federal Guidance Report 13, CD Supplement, Cancer Risk Coefficients for Environmental Exposure to Radionuclides, EPA* (DIRS 175544-EPA 2002, all) to estimate the unit risk factors. These dose coefficients are based on the recommendations by International Commission on Radiological Protection Publication 60 (DIRS 101836-ICRP 1991, all) and incorporate the dose coefficients from International Commission on Radiological Protection Publication 72 (DIRS 152446-ICRP 1996, all). For each radionuclide, the dose coefficients DOE used to estimate the unit risk factors, which are listed in *ICRP-60 and ICRP-72 RADTRAN 5 and RISKIND Dose Conversion Factors* (DIRS 176975-BMI 2006, Table 5), include radioactive progeny (DIRS 176975-BMI 2006, Table 2). Table 5 in that document also lists the lung absorption type and the value for the fractional absorption to blood from the small intestine (f_1) for each radionuclide.

G.7 Consequences of the Maximum Reasonably Foreseeable Transportation Accident

In addition to analyzing the radiological and nonradiological accident risks of transporting spent nuclear fuel and high-level radioactive waste, DOE evaluated severe transportation accidents to determine the consequences of the maximum reasonably foreseeable accident in the context of transporting spent nuclear fuel and high-level radioactive waste to Yucca Mountain. According to DOE guidance, accidents that have a frequency of less than 1×10^{-7} rarely need to be examined because they are not reasonably foreseeable (DIRS 172283-DOE 2002, p. 9). The maximum reasonably foreseeable accident analyzed in this Repository SEIS has a frequency greater than 1×10^{-7} per year.

The evaluation of severe transportation accidents was based on a review of the 20 rail accident severity categories identified in *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, pp. 7-73 and 7-76) that result in releases of radioactive material from a rail cask. The following list describes these severity categories:

- Case 20: Case 20 is a long-duration (many hours), high-temperature fire that would engulf a cask.

- Cases 19, 18, 17, and 16: Case 19 is a high-speed [more than 190 kilometers (120 miles) per hour] impact into a hard object, such as a train locomotive, severe enough to cause failure of cask seals and puncture through the cask's shield wall. The impact would be followed by a very-long-duration, high-temperature, engulfing fire. Cases 18, 17, and 16 are accidents that would also involve very-long-duration fires, failures of cask seals, and puncture of cask walls. However, these accidents would be progressively less severe in terms of impact speeds. The impact speeds range from 145 to 190 kilometers (90 to 120 miles) per hour for Case 18, 97 to 145 kilometers (60 to 90 miles) per hour for Case 17, and 48 to 97 kilometers (30 to 60 miles) per hour for Case 16.

- Cases 15, 12, 9, and 6: Case 15 is a high-speed [more than 190 kilometers (120 miles) per hour] impact into a hard surface, such as granite, severe enough to cause failure of cask seals. The impact would be followed by a long-duration, high-temperature engulfing fire. Cases 12, 9, and 6 are also accidents that would involve long-duration fires and failures of cask seals. However, these accidents would be progressively less severe in terms of impact speeds, ranging from 145 to 190 kilometers

(90 to 120 miles) per hour for Case 12, 97 to 145 kilometers (60 to 90 miles) per hour for Case 9, and 48 to 97 kilometers (30 to 60 miles) per hour for Case 6.

- Cases 14, 11, 8, and 5: Case 14 is a high-speed [more than 190 kilometers (120 miles) per hour] impact into a hard surface, such as granite, severe enough to cause failure of cask seals. The impact would be followed by a high-temperature engulfing fire that burned for hours. Cases 11, 8, and 5 are also accidents that would involve fires that would burn for hours and failures of cask seals. However, these accidents would be progressively less severe in terms of impact speeds, ranging from 145 to 190 kilometers (90 to 120 miles) per hour for Case 11, 97 to 145 kilometers (60 to 90 miles) per hour for Case 8, and 48 to 97 kilometers (30 to 60 miles) per hour for Case 5.

- Cases 13, 10, 7, and 4: Case 13 is a high-speed [more than 190 kilometers (120 miles) per hour] impact into a hard surface, such as granite, severe enough to cause failure of cask seals. The impact would be followed by an engulfing fire lasting more than 0.5 hour to a few hours. Cases 10, 7, and 4 are accidents that would involve long-duration fires and failures of cask seals. However, these accidents are progressively less severe in terms of impact speeds, ranging from 145 to 190 kilometers (90 to 120 miles) per hour for Case 10, 97 to 145 kilometers (60 to 90 miles) per hour for Case 7, and 48 to 97 kilometers (30 to 60 miles) per hour for Case 4.

- Cases 3, 2, and 1: Case 3 is a high-speed [more than 190 kilometers (120 miles) per hour] impact into a hard surface, such as granite, severe enough to cause failure of cask seals with no fire. Cases 2 and 1 are also accidents that would not involve fire but would have progressively lower impact speeds, 145 to 190 kilometers (90 to 120 miles) per hour for Case 2 and 97 to 145 kilometers (60 to 90 miles) per hour for Case 1.

The Spent Fuel Estimates document (DIRS 152746-Sprung et al. 2000, pp. 7-73 and 7-76) also evaluated Case 21, which is an accident that does not result in a release of radioactive material from a rail cask.

Each of the 20 accident cases above has an associated conditional probability of occurrence (DIRS 152476-Sprung et al. 2000, p. 7-76). These conditional probabilities were combined with the distances along the transportation routes presented in Section G.2, the shipment data presented in section G.3, and the accident rates discussed in Section G.6.1.1 to estimate the frequency of occurrence for each accident case. These frequencies are listed in Table G-19. Cases 1, 4, and 20 have frequencies greater than 1×10^{-7} per year. Based on the results presented in Table J-22 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Table J-22), Case 20 is estimated to have the highest consequences of these three accident cases. Therefore, Case 20 is considered to be the maximum reasonably foreseeable transportation accident.

Based on the analysis in the Yucca Mountain FEIS, accidents that would involve truck casks yielded lower consequences than accidents that would involve rail casks (DIRS 155970-DOE 2002, Tables J-22 and J-23). Therefore, DOE did not update severe accidents involving truck casks in this Repository SEIS.

DOE used the following assumptions to estimate the consequences of the maximum reasonably foreseeable accident (DIRS 157144-Jason Technologies 2001, Section 5.3.3.3):

- A release height of the plume of 10 meters (33 feet) for fire- and impact-related accidents. In the case of an accident with a fire, a 10-meter release height with no plume rise from the buoyancy of the

Table G-19. Annual frequencies for accident severity cases.

Accident severity case	Annual frequency (accidents per year)
1	8×10^{-7}
2	$5 \times 10^{-8} – 6 \times 10^{-8}$
3	$4 \times 10^{-10} – 5 \times 10^{-10}$
4	3×10^{-6}
5	8×10^{-8}
6	1×10^{-8}
7	7×10^{-9}
8	2×10^{-10}
9	$2 \times 10^{-11} – 3 \times 10^{-11}$
10	5×10^{-10}
11	1×10^{-11}
12	2×10^{-12}
13	4×10^{-12}
14	1×10^{-13}
15	1×10^{-14}
16	4×10^{-11}
17	$2 \times 10^{-14} – 3 \times 10^{-14}$
18	2×10^{-15}
19	1×10^{-17}
20	5×10^{-6}

plume due to fire conditions would yield higher estimates of consequences than accounting for the buoyancy of the plume from the fire (DIRS 157144-Jason Technologies 2001, p. 176).

- A breathing rate for individuals of 10,400 cubic meters (367,000 cubic feet) per year. DOE estimated this breathing rate from data in International Commission on Radiological Protection Publication 23 (DIRS 101074-ICRP 1975, p. 346).

- The release from a severe accident would include only respirable material (DIRS 157144-Jason Technologies 2001, p. 177). The deposition velocity for respirable material would be 0.01 meter per second (0.022 mile per hour).

- A short-term exposure time to airborne contaminants of 2 hours.

- A long-term exposure time to contamination deposited on the ground of one year, with no interdiction or cleanup.

- In the Yucca Mountain FEIS, DOE used two sets of atmospheric conditions—neutral atmospheric conditions and moderate winds speeds, and stable atmospheric conditions and low wind speeds—to determine consequences from severe accidents. Stable atmospheric conditions and low wind speeds yielded higher consequences than neutral atmospheric conditions and moderate wind speeds. Therefore, in this Repository SEIS, DOE used low wind speeds and stable atmospheric conditions [a wind speed of 0.89 meter per second (2 miles per hour) and Class F stability] to determine consequences. The atmospheric concentrations estimated from these atmospheric conditions would be exceeded only 5 percent of the time.

- Consequences were determined for a single rail cask containing 21 pressurized-water-reactor spent nuclear fuel assemblies.

- Each pressurized-water-reactor spent nuclear fuel assembly would have a burnup of 60,000 megawatt-days per MTHM, an enrichment of 4 percent, and a decay time of 10 years (DIRS 169061-BSC 2004, all). Table G-15 lists the radionuclide inventory for a single pressurized-water-reactor spent nuclear fuel assembly.

DOE used the RISKIND computer code (DIRS 101483-Yuan et al. 1995, all) to estimate radiation doses for the inhalation, groundshine, immersion, and resuspension pathways. RISKIND has been verified and validated for estimating radiation doses from transportation accidents involving radioactive material (DIRS 101845-Maheras and Pippen 1995, all; DIRS 102060-Biwer et al. 1997, all). In addition, DOE used the inhalation dose coefficients from *The ICRP Database of Dose Coefficients: Workers and Members of the Public* (DIRS 172935-ICRP 2001, all) and the groundshine and immersion dose coefficients from *Federal Guidance Report 13, CD Supplement, Cancer Risk Coefficients for Environmental Exposure to Radionuclides, EPA* (DIRS 175544-EPA 2002, all) to estimate radiation doses.

The analysis assumed that the maximum reasonably foreseeable transportation accident could occur anywhere along the transportation routes. Population densities in rural areas range from 0 to 54 people per square kilometer (0 to 139 people per square mile). DOE based the analysis in the rural area on a population density of 6 people per square kilometer, which is a representative population density for a rural area (DIRS 101892-NRC 1977, p. E-2). The Department estimated the population density in an urban area by identifying the 20 urban areas in the United States with the largest populations using 2000 Census data, determining the population density in successive annular rings around the center of each urban area, escalating these population densities to 2067, and averaging the population densities in each successive annular ring. Based on 2000 Census data, Las Vegas was not among the 20 largest urban areas in the United States. However, because of proximity of Las Vegas to the repository, DOE included it in the population density analysis. The resident population in Las Vegas was modified to include casino guests and casino workers. Table G-20 lists the population densities.

It should be noted that, based on the analysis in the Yucca Mountain FEIS, the maximum reasonably foreseeable accident involving truck casks would yield lower consequences than the maximum reasonably foreseeable accident involving rail casks (DIRS 155970-DOE 2002, Tables J-22 and J-23).

Table G-20. Population density in urban area.

Annular distance [kilometers (miles)]	Population density [people per square kilometer (people per square mile)[a]
0 to 8.05 (0 to 5)	5,012 (12,980)
8.05 to 16.09 (5 to 10)	2,956 (7,656)
16.09 to 24.14 (10 to 15)	2,112 (5,470)
24.14 to 32.19 (15 to 20)	1,342 (3,476)
32.19 to 40.23 (20 to 25)	899 (2,330)
40.23 to 80.47 (25 to 50)	299 (774)

Note: Population densities have been escalated to 2067.

G.8 Transportation Sabotage

DOE used the following assumptions to estimate the consequences of transportation sabotage events (DIRS 157144-Jason Technologies 2001, Section 5.3.4.2):

- A breathing rate for individuals of 10,400 cubic meters (367,000 cubic feet) per year. This breathing rate was estimated from data in International Commission on Radiological Protection Publication 23 (DIRS 101074-ICRP 1975, p. 346).

- A short-term exposure time to airborne contaminants of 2 hours.

- A long-term exposure time to contamination deposited on the ground of 1 year, with no interdiction or cleanup.

- As in the Yucca Mountain FEIS, DOE used moderate wind speeds and neutral atmospheric conditions [a wind speed of 4.47 meters per second (10 miles per hour) and Class D stability] to determine the consequences of sabotage.

- The release from a sabotage event would include respirable and nonrespirable material. The deposition velocity for respirable material would be 0.01 meter per second (0.022 mile per hour) and the deposition velocity for nonrespirable material would be 0.1 meter per second (0.22 mile per hour).

The DOE analysis assumed that in the sabotage event there would be an initial explosive release that involved releases of radioactive material at varying release heights. For 4 percent of the release, the analysis estimated a release height of 1 meter (3.3 feet); for 16 percent of the release, it estimated a release height of 16 meters (52 feet); for 25 percent of the release, it estimated a release height of 32 meters (100 feet); for 35 percent of the release, it estimated a release height of 48 meters (160 feet); and for 20 percent of the release, it estimated a release height of 64 meters (210 feet) (DIRS 157144-Jason Technologies 2001, p. 189).

In the Yucca Mountain FEIS, DOE used the release fraction data in Luna et al. (DIRS 104918-Luna et al. 1999, all) to evaluate the consequences of sabotage events. For truck and rail casks, a successful sabotage attempt that used the device called "high energy density device one" yielded the largest radiation doses. In this Repository SEIS, the Department used release fractions from Luna (DIRS 181279-Luna 2006, all) to estimate the impacts of such acts that involved spent nuclear fuel in truck or rail casks. The release fractions in Luna (DIRS 181279-Luna 2006, all) are based on the release fractions in Luna et al. (DIRS 104918-Luna et al. 1999, all), but they incorporate data from additional tests sponsored by *Gesellschaft für Anlagen - und Reaktorsicherheit* in Germany and conducted in France in 1994 that were not available for the 1999 report. These tests used pressurized fuel pins and provided a means to assess the effects of aerosol blowdown from pin plenum gas release. The use of these additional test data suggest that DOE overstated the consequences in the FEIS by a factor of 2.5 to 12.

For rail casks, the release fractions in Luna (DIRS 181279-Luna 2006, all) and Luna et al. (DIRS 104918-Luna et al 1999, all) were based on a rail cask that would hold 26 pressurized-water reactor spent nuclear fuel assemblies. DOE plans to operate the repository using a primarily canistered approach that calls for packaging most commercial spent nuclear fuel in TAD canisters, which would hold 21 pressurized-water reactor spent nuclear fuel assemblies. In this Repository SEIS, DOE chose to estimate the consequences of a rail sabotage event based on the radionuclide inventory in 26 pressurized-water reactor spent nuclear fuel assemblies, which overestimated consequences by about 24 percent in comparison with the inventory in 21 pressurized-water reactor spent nuclear fuel assemblies. For truck casks, the sabotage scenario involved a single truck cask that contained four pressurized-water reactor spent nuclear fuel assemblies.

Table G-15 lists the radionuclide inventory for a single pressurized-water reactor spent nuclear fuel assembly.

DOE used the RISKIND computer code (DIRS 101483-Yuan et al. 1995, all) to estimate radiation doses for the inhalation, groundshine, immersion, and resuspension pathways. The analysis assumed that the transportation sabotage event could occur anywhere, either in rural or urban areas, using the same population densities as those in the severe accident analysis in Section G.7.

G.9 Transportation Topical Areas

This section discusses topics identified by the public during the scoping process for this Repository SEIS and the Rail Alignment EIS.

G.9.1 ACCIDENTS INVOLVING HAZARDOUS CHEMICALS

DOE would use dedicated trains to ship most spent nuclear fuel and high-level radioactive waste, and hazardous chemical cargos would not be on the same train as spent nuclear fuel or high-level radioactive waste. This would greatly reduce the potential for accidents involving the spent nuclear fuel or high-level radioactive waste and hazardous chemicals.

G.9.2 CRITICALITY DURING ACCIDENTS

Criticality is the term used to describe an uncontrolled nuclear chain reaction. NRC regulations in 10 CFR Part 71 require that the casks used to ship spent nuclear fuel and high-level radioactive waste be able to survive accident conditions, such as immersion in water, without undergoing a criticality. To meet this requirement, casks are typically designed such that, even if water filled the cask and the cask contained unirradiated nuclear fuel (the most reactive case from the perspective of a criticality), a criticality would not occur.

G.9.3 AIRCRAFT CRASH

An aircraft crash into a spent nuclear fuel or high-level radioactive waste cask would be extremely unlikely because the probability of a crash into such a relatively small object, whether stationary or moving, is extremely remote. Nevertheless, the Yucca Mountain FEIS analyzed the consequences of an accident in which a large commercial aircraft or a military aircraft is hypothesized to impact directly onto a cask (DIRS 155970-DOE 2002, Section J.3.3.1). The analysis showed that the penetrating force of a jet engine's center shaft would not breach the heavy shield wall of a cask. With the exception of engines, the relatively light structures of an aircraft would be much less capable of causing damage to a cask. A resulting fire would not be sustainable or able to engulf a cask long enough to breach its integrity.

The *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all), and the *Final Environmental Impact Statement, Withdrawal of Public Lands for Range Safety and Training Purposes, Naval Air Station Fallon, Nevada* (DIRS 148199-USN 1998, all) discussed system malfunctions or material failures that could result in either an accidental release of ordnance or release of a practice weapon. The *Special Nevada Report* (DIRS 153277-SAIC 1991, all) stated that the probability of dropped ordnance that resulted in injury, death, or property damage ranges from about 1 in 1 billion to 1 in 1 trillion per dropped ordnance incident, with an average of about 1 in 10 billion per incident. Less than one accidentally dropped ordnance incident is estimated per year for all flight operations over the Nevada Test and Training Range and Naval Air Station Fallon. Spent nuclear fuel transportation would not affect the risk from dropped ordnance or aircraft crashes. Therefore, this Repository SEIS does not evaluate radiological consequences of an impact of accidentally dropped ordnance on a transportation cask because the probability of such an event (about 1 in 10 billion per year) is not reasonably foreseeable. Therefore, DOE believes there would be no need for associated mitigation measures and no impacts on military operations.

G.9.4 BALTIMORE TUNNEL FIRE

On July 18, 2001, a freight train carrying hazardous (nonnuclear) materials derailed and caught fire while passing through the Howard Street railroad tunnel in downtown Baltimore, Maryland. The NRC evaluated possible impacts of this fire in *Spent Nuclear Fuel Transportation Package Response to the Baltimore Tunnel Fire Scenario* (DIRS 182014-Adkins et al. 2006, all).

This study evaluated the response of three transportation casks—the HOLTEC Model No. HI-STAR 100, the TransNuclear Model No. TN-68, and the Nuclear Assurance Corporation Legal Weight Truck—to the conditions that existed during the fire. The study concluded that larger transportation packages that resembled the HI-STAR 100 and TN-68 would withstand a fire with thermal conditions similar to those that existed in the Baltimore tunnel fire event with only minor damage to peripheral components. This would be due to their sizable thermal inertia and design specifications in compliance with currently imposed regulatory requirements.

For the TN-68 and the Nuclear Assurance Corporation Legal Weight Truck casks, the maximum temperatures predicted in the regions of the lid and the vent and drain ports exceed the seals' rated service temperatures, making it possible for a small release to occur due to crud that might spall off the surfaces of the fuel rods. While a release is not expected for these conditions, any release that could occur would be very small due to the following factors: (1) the tight clearances maintained between the lid and cask body by the closure bolts, (2) the low pressure differential between the cask interior and exterior, (3) the tendency of such small clearances to plug, and (4) the tendency of crud particles to settle or plate out.

The NRC study also evaluated the radiological consequences of the package responses to the Baltimore tunnel fire. The analysis indicated that the regulatory dose rate limits specified in 10 CFR 71.51 for accident conditions would not be exceeded by releases or direct radiation from any of these packages in this fire scenario. All three packages are designed to maintain regulatory dose rate limits even with a complete loss of neutron shielding. While highly unlikely, the Nuclear Assurance Corporation Legal Weight Truck cask could experience some decrease in gamma shielding due to slump in the lead as a consequence of this fire scenario, but a conservative analysis showed that the regulatory dose rate limits would not be exceeded.

The results of this evaluation strongly indicate that neither spent nuclear fuel particles nor fission products would be released from a spent fuel transportation cask carrying intact spent nuclear fuel involved in a severe tunnel fire such as the Baltimore Tunnel Fire. None of the three cask designs analyzed for the Baltimore Tunnel fire scenario (TN-68, HI-STAR 100, and Nuclear Assurance Corporation Legal Weight Truck) experienced internal temperatures that would result in rupture of the fuel cladding. Therefore, radioactive material (spent nuclear fuel particles or fission products) would be retained in the fuel rods.

There would be no release from the HI-STAR 100 because the inner welded canister would remain leak tight. While a release is unlikely, the potential releases calculated for the TN-68 rail cask and the Legal Weight Truck cask indicated that any release of crud from either cask would be very small—less than an A_2 quantity. The release of an A_2 quantity is approximately equivalent to a radiation dose of 5 rem.

The NRC also evaluated the response of the Nuclear Assurance Corporation Legal Weight Truck cask to the conditions present during the Caldecott Tunnel fire in *Spent Fuel Transportation Package Response to the Caldecott Tunnel Fire Scenario* (DIRS 181841-Adkins et al. 2007, all). This fire took place on April 7, 1982, when a tank truck and trailer carrying 33,300 liters (8,800 gallons) of gasoline was involved in an accident in the Caldecott Tunnel on State Route 24 near Oakland, California. The trailer overturned and subsequently caught fire. This event is one of the most severe of the five major highway tunnel fires involving shipments of hazardous material that have occurred world-wide since 1949.

This study concluded that small transportation casks similar to the Nuclear Assurance Corporation Legal Weight Truck cask would probably experience degradation of some seals in this severe accident scenario. The maximum temperatures predicted in the regions of the cask lid and the vent and drain ports exceed the rated service temperature of the tetrafluoroethylene or Viton seals, making it possible for a small release to occur due to crud that could spall off the surfaces of the fuel rods. However, any release is expected to be very small due to a number of factors: (1) the metallic lid seal does not exceed its rated service temperature and therefore can be assumed to remain intact, (2) the tight clearances maintained by the lid closure bolts, (3) the low pressure differential between the cask interior and exterior, (4) the tendency for solid particles to plug small clearance gaps and narrow convoluted flow paths such as the vent and drain ports, and (5) the tendency of crud particles to settle or plate out and, therefore, not be available for release.

The NRC study also evaluated the radiological consequences of the package response to the Caldecott Tunnel fire. The results of this evaluation strongly indicate that neither spent nuclear fuel particles nor fission products would be released from a spent fuel transportation cask involved in a severe tunnel fire such as the Caldecott Tunnel fire. The Nuclear Assurance Corporation Legal Weight Truck cask design analyzed for the Caldecott Tunnel fire scenario does not reach internal temperatures that could result in rupture of the fuel cladding. Therefore, radioactive material (spent nuclear fuel particles or fission products) would be retained in the fuel rods. The potential release calculated for the Legal Weight Truck cask in this scenario indicates that any release of crud from the cask would be very small—less than an A_2 quantity. The release of an A_2 quantity is approximately equivalent to a radiation dose of 5 rem.

G.9.5 CASK RECOVERY

The recovery of rail casks loaded with spent nuclear fuel or high-level radioactive waste would use methods commonly used to recover railcars and locomotives following accidents. The capability to lift such weights exists and would be deployed as required. Railroads use emergency response contractors with the ability to lift derailed locomotives that could weigh as much as 136 metric tons (150 tons). Difficult recoveries of equipment as heavy as spent nuclear fuel casks have occurred and DOE anticipates that, if such a recovery was necessary, it would use methods and equipment similar to those used in prior difficult recoveries.

G.9.6 HUMAN ERROR AND TRANSPORTATION ACCIDENTS

Several types of human error could be involved in transportation; some of which could contribute to accident consequences. One type of human error that could contribute to accident consequences would be errors involving transport vehicle operators, operators of other vehicles, or persons who maintained vehicles and rights-of-way. The accident rates (see Section G.6.1.1) and conditional probabilities and release fractions (see Section G.6.1.2) used to estimate the risks and consequences from accidents involving truck and rail shipments account for this type of human error. The doses and associated health effects to workers and the public are presented in Section 6.3.

The State of Nevada suggested that other types of human error could contribute to accident consequences including: (1) errors in the preparation of the casks (packages) for shipment, (2) undetected errors in the design of transportation casks, and (3) undetected defects during the manufacture of casks. In addition, the State suggested that willful violations of regulations and procedures that guide the design and fabrication of casks, and the preparation of casks for shipment could exacerbate accident consequences. The exact nature of human error and whether such incidents were to occur singly or in combination are inherently uncertain—the possibilities are endless.

Errors in cask preparation, for example, could involve, either singly or in combination, defective tie-down bolts or bolts that are tightened insufficiently (or over tightened), defective or loose or over tightened cask lid bolts, use of unapproved or obsolete lid seals, and faulty test procedures. Even so, when considered as a category, the error rate for cask preparation and loading is estimated to be about 1 in 1,000 (DIRS 185491-Hughes et al. 2006, all; DIRS 185493-Longfellow and Haslett 2002, all). For truck shipments of commercial spent nuclear fuel, the probability of any accident occurring is about 1 in 500 shipments and, when coupled with an error in cask preparation or loading, would be about 1 chance in 500,000 shipments. For rail shipments of commercial spent nuclear fuel (3 to 5 casks per shipment), the probability of any accident occurring would range from about 1 in 300 to 1 in 400 shipments and, when coupled with an error in cask preparation or loading, would be about 1 chance in 80,000 shipments to about 1 chance in 90,000 shipments. Since DOE would make about 2,650 truck shipments and 2,833 rail shipments of commercial spent nuclear fuel and high-level radioactive waste (under the Proposed Action), an accident involving either truck or rail casks that were not properly loaded or prepared for shipping would be very unlikely and therefore not expected to occur.

Errors in the design and fabrication of casks, or in the willful violation during such design and fabrication could occur singly or in various combinations. To demonstrate, *A Review of the Effects of Human Error on the Risks Involved in Spent Fuel Transportation* (DIRS 185494-Audin 1987, pp. 19 to 24) identifies more than 20 separate human error scenarios involving cask design, manufacturing and maintenance, and the ways in which accidents could be handled.

DOE is required, pursuant to the NWPA, to use casks that have been certified by the NRC to ship spent nuclear fuel and high-level radioactive waste. The procedures by which NRC certifies a cask design are described in the *Standard Review Plan for Transportation Packages for Spent Nuclear Fuel* (DIRS 154000-NRC 2000, all). Detailed evaluations are required to be conducted of the cask's structural and thermal design, containment system, shielding, and the ability of the cask to satisfy criticality safety requirements. NRC does not require a "human reliability analysis" as a means to address human error when certifying a cask (a relatively passive containment device) as it does for more complex systems involving the handling of spent nuclear fuel, such as a commercial reactor or the proposed Yucca Mountain repository.

Further, DOE has committed in its Record of Decision (69 FR 18557, April 8, 2004) that it would follow NRC regulations related to the shipping of spent nuclear fuel and high-level radioactive waste. These regulations address cask operating procedures, cask acceptance tests, and cask maintenance programs. NRC requires procedures for loading and unloading a cask, acceptance tests to ensure that casks are fabricated in accordance with the design, and inspections to detect cracks, pinholes, uncontrolled voids, or other defects (for example, visual inspections and measurements, weld inspections, structural and pressure tests, leakage tests, shielding tests, neutron absorber tests, and thermal tests).

In addition, NRC has issued quality assurance requirements related to the design, manufacturing, and use of casks, and requirements for inspections of transportation activities. The requirements for these quality assurance programs are contained in 10 CFR Part 71, Subpart H. Guidance for establishing these quality assurance programs is contained in NRC Regulatory Guide 7.10, *Establishing Quality Assurance Programs for Packaging Used in Transport of Radioactive Material* (DIRS 185496-NRC 2005, all).

NRC also requires inspections of the manufacturers of spent nuclear fuel casks. The procedures for carrying out these inspections, which are described in *Quality Assurance Inspections for Shipping and Storage Containers* (DIRS 185497-Stromberg et al. 1996, all), address management controls, design controls, fabrication controls, and maintenance controls. Inspections are required to verify that all phases of the fabrication process are controlled and implemented, and the fabrication process is required to be controlled and verifiable from the onset of design through the completion of the manufacturing process. NRC Inspection Procedure 86001, *Design, Fabrication, Testing, and Maintenance of Transportation Packaging* (DIRS 185498-NRC 2008, all) would be used to conduct these inspections. Inspections of manufacturers of spent nuclear fuel casks would involve observing these activities to verify that they are performed in accordance with approved methods, procedures, and specifications, and that the individuals performing these activities are properly trained and qualified.

Regarding the shipment of spent nuclear fuel and high-level radioactive waste to the repository in NRC-certified casks, DOE would meet or exceed NRC requirements related to the inspection of transportation activities. NRC's procedures for inspections of transportation activities are described in NRC Inspection Procedure 86740, *Inspection of Transportation Activities* (DIRS 185499-NRC 2002, all). These procedures involve observations of the preparation of spent nuclear fuel casks for shipment, delivery of spent nuclear fuel casks to carriers, and receipt of spent nuclear fuel casks to verify that they are performed in accordance with approved methods, procedures, and specifications, and that the individuals performing these activities are properly trained and qualified.

DOE's analysis of potential accidents considered low probability-high consequence scenarios, including the most severe accidents that reasonably could occur (see Appendix G, Sections G.6 and G.7). DOE could analyze additional accident scenarios involving a combination of an extremely unlikely accident scenario compounded by human error, such as faulty welds or failed seals. DOE also could analyze accident scenarios involving other combinations of factors, such as multiple rail casks on a train having the same undetected design flaw and in which each cask had been fabricated improperly. As with any aspect of environmental impact analysis, it is always possible to postulate scenarios that could produce higher consequences than previous estimates. In eliminating the requirement that agencies conduct a worst-case analysis, the Council on Environmental Quality has pointed out that "one can always conjure up a worse ‘worst case’” by adding more variables to a hypothetical event (50 FR 32234, August 8, 1985), but that “‘worst case analysis’ is an unproductive and ineffective method…one which can breed endless hypothesis and speculation” (51 FR 15620, April 25, 1986).

The Council on Environmental Quality regulations that implement the National Environmental Policy Act (NEPA) require federal agencies to address reasonably foreseeable significant adverse effects. The evaluation of impacts, however, is subject to a “rule of reason” designed to ensure analyses based on credible scientific evidence that is useful to the decisionmaking process. In applying the rule of reason, an agency need not address remote and highly speculative consequences in its EIS.

For reasons discussed aabove, consideration of accidents involving a release of radioactive material from either truck or rail casks that were not properly loaded or prepared for shipping would violate the rule of reason. DOE accordingly has not considered such accidents in this Repository SEIS..

G.9.7 COST OF CLEANUP

According to the NRC report *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, pp. 7 to 76), in more than 99.99 percent of accidents radioactive material would not be released from the cask. After initial safety precautions had been taken, the cask would be recovered and removed from the accident scene. Because no radioactive material would be released, based on reported experience with two previous accidents (DIRS 156110-FEMA 2000, Appendix G, Case 4 and Case 5), the economic costs of these accidents would be minimal.

For the 0.01 percent of accidents severe enough to cause a release of radioactive material from a cask, a number of interrelated factors would affect costs of cleaning up the resulting radioactive contamination after the accident: the severity of the accident and the initial level of contamination; the weather at the time and following; the location and size of the affected land area and the use of the land; the established standard for the allowable level of residual contamination following cleanup and the decontamination method used; and the technical requirements and location for disposal of contaminated materials.

Because it would be necessary to specify each of the factors to estimate cleanup costs, an estimate for a single accident would be highly uncertain and speculative. Nevertheless, to provide a gauge of the costs that could occur DOE examined past studies of costs of cleanup following hypothetical accidents that would involve uncontrolled releases of radioactive materials.

An NRC study of the impacts of transporting radioactive materials in 1977 estimated that costs could range from about $1 million to $100 million for a transportation accident that involved a 600-curie release of a long-lived radionuclide (DIRS 101892-NRC 1977, Table 5-11). These estimates would be about 3 times higher if escalated for inflation from 1977 to the present. In 1980, Finley et al. (DIRS 155054-Finley et al. 1980, Table 6-9) estimated that costs could range from about $90 million to $2 billion for a severe spent nuclear fuel transportation accident in an urban area. Sandquist et al. (DIRS 154814-Sandquist et al. 1985, Table 3-7) estimated that costs could range from about $200,000 to $620 million. In this study, Sandquist et al. estimated that contamination would affect between 0.063 to 4.3 square kilometers (16 to 1,100 acres). A study by Chanin and Murfin (DIRS 152083-Chanin and Murfin 1996, Chapter 6) estimated the costs of cleanup following a transportation accident in which plutonium was dispersed. This study developed cost estimates for cleaning up and remediating farmland, urban areas, rangeland, and forests. The estimates ranged from $38 million to $400 million per square kilometer that would need cleanup. In addition, the study evaluated the costs of expedited cleanups in urban areas for light, moderate, and heavy contamination levels. These estimates ranged from $89 million to $400 million per square kilometer.

The National Aeronautics and Space Administration studied potential accidents for the Cassini mission, which used a plutonium-powered electricity generator. The Administration estimated costs of cleaning up radioactive material contamination on land following potential launch and reentry accidents. The estimate for the cost following a launch accident ranged from $7 million to $70 million (DIRS 155551-NASA 1995, Chapter 4) with an estimated contaminated land area of about 1.4 square kilometers (350 acres). The Administration assumed cleanup costs would be $5 million per square kilometer if removal and disposal of contaminated soil were not required and $50 million per square kilometer if those activities were required. For a reentry accident that occurred over land, the study estimated that the contaminated area could range from about 1,500 to 5,700 square kilometers (370,000 to 1.4 million acres) (DIRS 155551-NASA 1995, Chapter 4) with cleanup costs possibly exceeding a total of $10 billion. In a more recent study of potential consequences of accidents that could involve the Cassini mission, the Administration estimated that costs could range from $7.5 million to $1 billion (DIRS 155550-NASA 1997, Chapter 4). The contaminated land area associated with these costs ranged from 1.5 to 20 square kilometers (370 to 4,900 acres). As in the 1995 study, these estimates were based on cleanup costs in the range of $5 million to $50 million per square kilometer.

Using only the estimates provided by these studies, the costs of cleanup following a severe transportation accident in which radioactive material was released could be in the range from $300,000 (after adjusting for inflation from 1985 to the present) to $10 billion. Among the reasons for this wide range are different assumptions about the factors that must be considered: (1) the severity of the assumed accident and resulting contamination levels, (2) accident location and use of affected land areas, (3) meteorological conditions, (4) cleanup levels and decontamination methods, and (5) disposal of contaminated materials. However, the extreme high estimates of costs are based on assumptions that all factors combine in the most disadvantageous way to create a worst case. Such worst cases are not reasonably foreseeable. Conversely, estimates as low as $300,000 might not be realistic for all of the direct and indirect costs of cleaning up following an accident severe enough to cause a release of radioactive materials.

To gauge the range of costs that it could expect for severe accidents during the transport of spent nuclear fuel to a Yucca Mountain repository, DOE considered the amount of radioactive material that could be released in the maximum reasonably foreseeable transportation accident and compared this with the estimates of releases used in the studies discussed above. The maximum reasonably foreseeable transportation accident would release about 30 curies (mostly cesium). This is about 50 times less than the release used by Sandquist et al. (DIRS 154814-Sandquist et al. 1985, all) (1,630 curies) and 20 times less than the release used in the estimates provided by the NRC in 1977 (600 curies). The estimated frequency for an accident this severe to occur is about 6 or 7 times in 10 million years. Based on the prior studies (in which estimated releases exceeded those estimated in this appendix for a maximum reasonably foreseeable transportation accident) and the amount of radioactive material that could be released in a maximum reasonably foreseeable transportation accident, DOE believes that the cost of cleaning up following such an accident could be a few million dollars. Nonetheless, as stated above, the Department also believes that estimates of such costs contain great uncertainty and are speculative; they could be less or 10 times greater, depending on the contributing factors.

For perspective, the current insured limit of responsibility for an accident that involves releases of radioactive materials to the environment is \$10.26 billion (Appendix H).

OPPOSING VIEW: COSTS OF CLEANUP

The State of Nevada has provided analyses that assert that the costs of cleanup could be much higher than the estimates discussed in this Repository SEIS; up to \$189.7 billion for accidents that involved rail casks (DIRS 181756-Lamb et al. 2001, p. 48) and up to \$299.4 billion for sabotage that involved a rail cask (DIRS 181892-Lamb et al. 2002, p. 15).

The State estimated these costs based upon contamination levels that were estimated using computer programs that DOE developed and uses. However, the State's analysis used values for parameters that would be at or near their maximum values. DOE guidance for the evaluation of accidents in environmental impact statements (DIRS 172283-DOE 2002, p. 6) specifically cautions against the evaluation of scenarios for which conservative (or bounding) values are selected for multiple parameters because the approach yields unrealistically high results. Therefore, DOE believes that the State of Nevada estimates are unrealistic and that they do not represent the reasonably foreseeable cleanup costs of severe transportation accidents.

G.9.8 UNIQUE LOCAL CONDITIONS

Scoping comments on this Repository SEIS stated the unique local conditions in Nevada require special consideration in the transportation accident analysis. In this SEIS, DOE analyzed a range of severe accidents and their frequencies of occurrence (see Table G-19). The annual probabilities (frequencies of occurrence) provided in Table G-19 reflect the probability that the severe transportation accidents in Cases 1 through 20 (DIRS 152476-Sprung et al. 2000, all) could occur anywhere along the transportation routes. If analyses were prepared for specific urban locations, the annual probability of these severe accident cases would change as a result of the reduced number of shipments through the specific urban area and the shorter distances relative to the total transportation campaign. For instance, the annual probability of a Case 20 severe accident (the maximum reasonably foreseeable accident) occurring within the urban and suburban population density areas of Las Vegas at any time during the Proposed Action transportation campaign would be about 3×10^{-9} per year, which is nearly 2 orders of magnitude below that which is reasonably foreseeable. For these specific locations (including Las Vegas), the most severe accident that would be reasonably foreseeable (with an annual probability greater than 1×10^{-7}) would be an accident similar to Case 21 from *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, pp. 7-73 and 7-76). This particular accident would not result in any release of radioactive material from the cask, and thus would result in smaller consequences than the maximum reasonably foreseeable accident that DOE evaluated, less than 1 latent cancer fatality (0.0005) as compared with 9.4 latent cancer fatalities as reported in Chapter 6, Table 6-7 for the maximum reasonable transportation accident in an urban area.

G.9.9 COMPREHENSIVE RISK ASSESSMENT

The State of Nevada recommended that DOE should use comprehensive risk assessment as a substitute for probabilistic risk assessment in the transportation analysis. According to the State, comprehensive risk assessment calculates probabilities only if there are existing data, theories, and models to support use of rigorous quantitative methods, and uses sensitivity analysis to illustrate impacts of differing assumptions and variations in the quality of data.

Probabilistic risk assessment has been and continues to be the standard tool used for transportation risk assessments since the NRC published the *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* in 1977 (DIRS 101892-NRC 1977, all). DOE used probabilistic risk assessment to estimate transportation impacts in this Repository SEIS because there are adequate data, methods, and computer programs that make it a valid, state-of-the-art tool to estimate transportation impacts. In addition, DOE has performed sensitivity analyses related to transportation impacts; these analyses are discussed in Appendix A.

G.9.10 BARGE SHIPMENTS

DOE evaluated the impacts of barge shipments of spent nuclear fuel in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Section J.2.4) for those generator sites without direct rail access but with barge access. The impacts of the use of barges to ship spent nuclear fuel from the generator sites without direct rail access were similar to the those of using heavy-haul trucks to ship from the generator sites without direct rail access for the mostly rail scenario (DIRS 155970-DOE 2002, Tables J-29, J-30, and J-32). The estimated exposed population along the barge routes analyzed in the FEIS was 502,132 people (DIRS 157144-Jason Technologies 2001, Table 3-10).

For this Repository SEIS, DOE used the TRAGIS computer program to reevaluate the representative routes that could be used for barge shipments of spent nuclear fuel (DIRS 181276-Johnson and Michelhaugh 2003, all). Table G-21 lists the sites, the locations of the intermodal transfer between the barge and the railroad, the lengths of the barge route, and the exposed populations along the barge route. In some cases, DOE evaluated multiple locations for the intermodal transfer.

For the 16 generator sites without direct rail access but with barge access listed in Table G-21, the estimated exposed population along the barge routes would range from 199,743 to 419,495 people. This exposed population would be less than or similar to the exposed population estimated in the Yucca Mountain FEIS. The locations of the intermodal transfer between the barge and the railroad were similar to the locations analyzed in the FEIS (DIRS 155970-DOE 2002, Table J-27) and the distances were similar to the distances estimated in the FEIS (DIRS 155970-DOE 2002, Table J-26). Because the exposed populations, distances, and intermodal transfer locations were similar to the exposed populations, distances, and intermodal transfer locations analyzed in the Yucca Mountain FEIS, the resulting impacts of using barge shipments would also be similar to the impacts of using barge shipments in the Yucca Mountain FEIS, and DOE did not evaluate barge shipments further in this Repository SEIS.

G.9.11 USE OF NUREG/CR-6672 TO ESTIMATE ACCIDENT RELEASES

The evaluations of the radiological impacts of transportation accidents in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Chapter 6) are based on data in NUREG/CR-6672, *Reexamination of Spent Nuclear Fuel Shipment Risk Estimates*, (DIRS 152476-Sprung et al. 2000, all) on conditional probabilities for the occurrence of severe accidents and on corresponding fractions of cask contents that could be released in such accidents.

In September 1977, the NRC issued a generic EIS, *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NUREG-0170; DIRS 101892-NRC 1977, all). This EIS addressed environmental impacts associated with the transport of all types of radioactive material by all transport modes (road, rail, air, and water). It provided the basis under NEPA for the NRC to issue

Table G-21. Data used in reevaluation of barge shipments.

Site	Distance (kilometers)[a]	Exposed population	Barge port assumed for barge-to-rail intermodal transfer
Browns Ferry	6.9	1	Port of Decatur
Browns Ferry	65.2	1,458	Port of Sheffield
Diablo Canyon	249.7	1,514	Port Hueneme
Humboldt Bay	435.5	550	Port of Oakland
Haddam Neck	75.1	3,557	Port of New Haven
Haddam Neck	55.8	3,593	Port of New London
St. Lucie	141.2	155,517	Port Everglades
St. Lucie	175.0	204,530	Port of Miami
St. Lucie	20.7	355	Port of Fort Pierce
Calvert Cliffs	110.8	2,213	Port of Baltimore
Calvert Cliffs	189.1	63	Port of Norfolk
Palisades	102.4	16	Port of Muskegon
Grand Gulf	51.6	32	Port of Vicksburg
Cooper	117.1	2,780	Port of Omaha
Hope Creek	30.3	85	Port of Wilmington
Hope Creek	69.5	1,159	Port of Philadelphia
Hope Creek	131.6	6,052	Port of Baltimore
Oyster Creek	131.3	43,595	Port of Newark
Salem	31.6	85	Port of Wilmington
Salem	70.8	1,159	Port of Philadelphia
Salem	132.9	6,052	Port of Baltimore
Indian Point	89.6	59,215	Port of Newark
Surry	59.8	43	Port of Norfolk
Kewaunee	149.0	43,977	Port of Milwaukee
Point Beach	142.5	43,875	Port of Milwaukee
Total	1,784.6 – 2,297.4	199,743 – 419,495	

a. To convert kilometers to miles, multiply by 0.62137.

general licenses for transportation of radioactive material under 10 CFR Part 71. Based in part on the findings of the EIS, the NRC concluded that “present regulations are adequate to protect the public against unreasonable risk from the transport of radioactive materials” (46 FR 21629, April 13, 1981) and stated that “regulatory policy concerning transportation of radioactive materials be subject to close and continuing review.”

In 1996, the NRC decided to reexamine the risks associated with the shipment of spent power reactor fuel by truck and rail to determine if the estimates of environmental impacts in NUREG-0170 (DIRS 101892-NRC 1977, all) remained valid. According to the Commission, the reexamination was initiated because (1) many spent fuel shipments are expected to be made during the next few decades, (2) these shipments will be made to facilities along routes and in casks not specifically examined by NUREG-0170, and (3) the risks associated with these shipments can be estimated using new data and improved methods of analysis. In 2000, the NRC published the results of the reexamination in a report prepared by the Sandia National Laboratories, *Reexamination of Spent Nuclear Fuel Shipment Risk Estimates* (NUREG/CR-6672; DIRS 152476-Sprung et al. 2000, all).

Some have been critical of NUREG/CR-6672 (for example, see DIRS 181884-Lamb and Resnikoff 2000, all, and DIRS 181756-Lamb et al. 2001, Appendix A). However, the NRC has stated that that many of the purported methodological flaws appear to be related to differing views on assumptions and that critical comments do not appear to recognize that many of the assumptions overstated risks (DIRS 181603-Shankman 2001, all).

Supporting the NRC assessment, in its review of NUREG/CR-6672, see *Going the Distance? The Safe Transport of Spent Nuclear and High-Level Radioactive Waste in the United State*, the National Academy of Sciences Committee on Transportation of Radioactive Waste noted that the conservative assumptions were reasonable for producing bounding estimates of accident consequences (DIRS 182032-National Research Council 2006, all). Conversely, the Committee indicated less confidence about the analysis of overall transport risks in the report. The Committee noted that the truck and rail routes used in the analyses were based on realistic, not bounding characteristics. The Committee considered "many other uncertainties" and ultimately concluded that the overall results of the "Sandia analyses are likely to be neither realistic nor bounding and 'probably' overestimate transport risks."

Based on the review by the National Academy of Sciences and comments made by NRC, DOE has concluded that NUREG/CR-6672 (DIRS 152476-Sprung et al. 2000, all) represents the best available information for use in estimating the consequences of transportation accidents that involve spent nuclear fuel and high-level radioactive waste and has used it in this Repository SEIS.

G.10 State-Specific Impacts and Route Maps

This section contains tables (G-22 through G-66) and maps (Figures G-3 through G-47) that illustrate the estimated impacts to 44 states and the District of Columbia (Alaska and Hawaii are not included; estimated impacts in Delaware, Montana, North Dakota, and Rhode Island would be zero). As discussed above, DOE used state- and route-specific data to estimate transportation impacts. At this time, about 10 years before shipments could begin, DOE has not determined the specific routes it would use to ship spent nuclear fuel and high-level radioactive waste to the proposed repository. Therefore, the transportation routes discussed in this section might not be the exact routes used for shipments to Yucca Mountain. Nevertheless, because the analysis is based primarily on the existing Interstate Highway System and the existing national rail network, the analysis presents a representative estimate of what the actual transportation impacts would probably be.

Table G-22. Estimated transportation impacts for the State of Alabama.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	1,514	3.9	62	0.0024	0.037	0.0030	0.011	6.3×10^{-6}	0.0087	0.052
Truck	857	4.7	7.5	0.0028	0.0045	0.0018	9.0×10^{-4}	5.4×10^{-7}	0.0052	0.014
Total	2,371	8.7	70	0.0052	0.042	0.0047	0.011	6.9×10^{-6}	0.014	0.066
Mina										
Rail	1,514	3.9	62	0.0024	0.037	0.0030	0.011	6.3×10^{-6}	0.0087	0.052
Truck	857	4.7	7.5	0.0028	0.0045	0.0018	9.0×10^{-4}	5.4×10^{-7}	0.0052	0.014
Total	2,371	8.7	70	0.0052	0.042	0.0047	0.011	6.9×10^{-6}	0.014	0.066

a. Totals might differ from sums of values due to rounding.

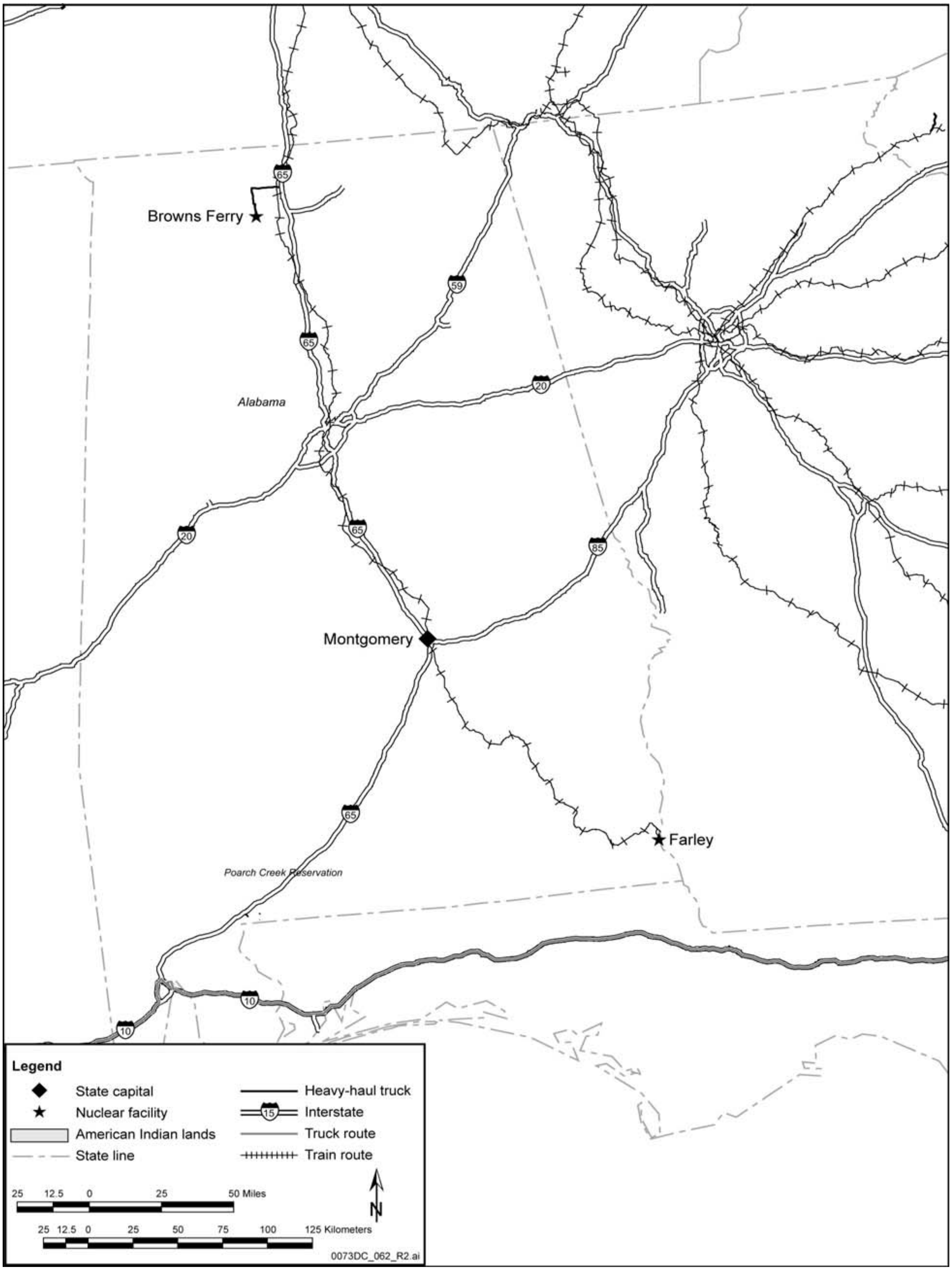

Figure G-3. Representative transportation routes for the State of Alabama.

Table G-23. Estimated transportation impacts for the State of Arizona.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	456	18	35	0.011	0.021	0.025	0.092	5.5×10^{-5}	0.016	0.073
Truck	2,650	15	38	0.0090	0.023	0.0055	0.0013	7.9×10^{-7}	0.029	0.066
Total	3,106	33	74	0.020	0.044	0.030	0.093	5.6×10^{-5}	0.045	0.14
Mina										
Rail	357	15	30	0.0092	0.018	0.021	0.077	4.6×10^{-5}	0.013	0.060
Truck	2,650	15	38	0.0090	0.023	0.0055	0.0013	7.9×10^{-7}	0.029	0.066
Total	3,007	30	68	0.018	0.041	0.026	0.078	4.7×10^{-5}	0.041	0.13

a. Totals might differ from sums of values due to rounding.

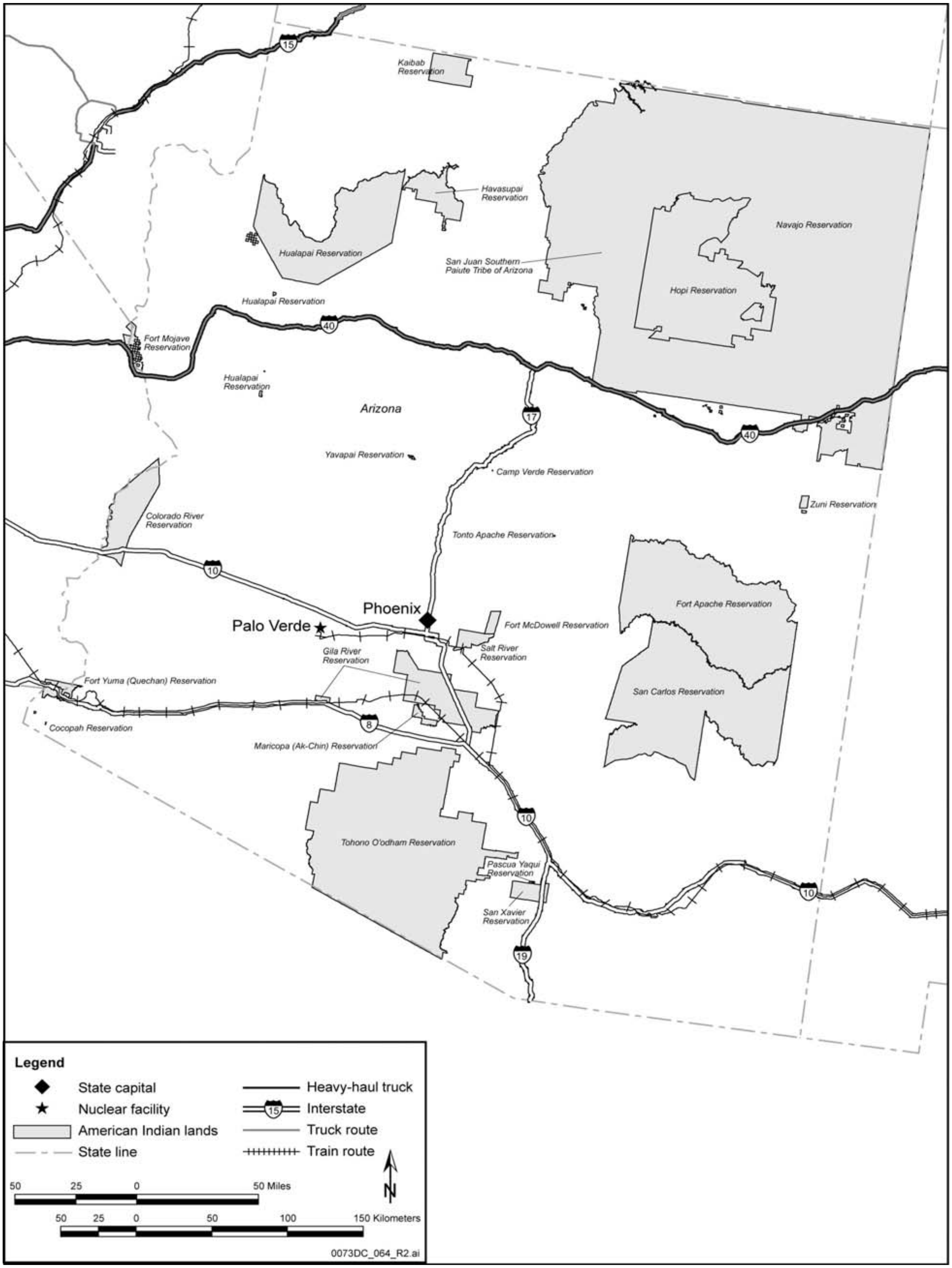

Figure G-4. Representative transportation routes for the State of Arizona.

Table G-24. Estimated transportation impacts for the State of Arkansas.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	227	0.46	11	2.7×10^{-4}	0.0063	6.7×10^{-4}	0.0035	2.1×10^{-6}	0.0026	0.0098
Truck	0	0	0	0	0	0	0	0	0	0
Total	227	0.46	11	2.7×10^{-4}	0.0063	6.7×10^{-4}	0.0035	2.1×10^{-6}	0.0026	0.0098
Mina										
Rail	227	0.46	11	2.7×10^{-4}	0.0063	6.7×10^{-4}	0.0035	2.1×10^{-6}	0.0026	0.0098
Truck	0	0	0	0	0	0	0	0	0	0
Total	227	0.46	11	2.7×10^{-4}	0.0063	6.7×10^{-4}	0.0035	2.1×10^{-6}	0.0026	0.0098

a. Totals might differ from sums of values due to rounding.

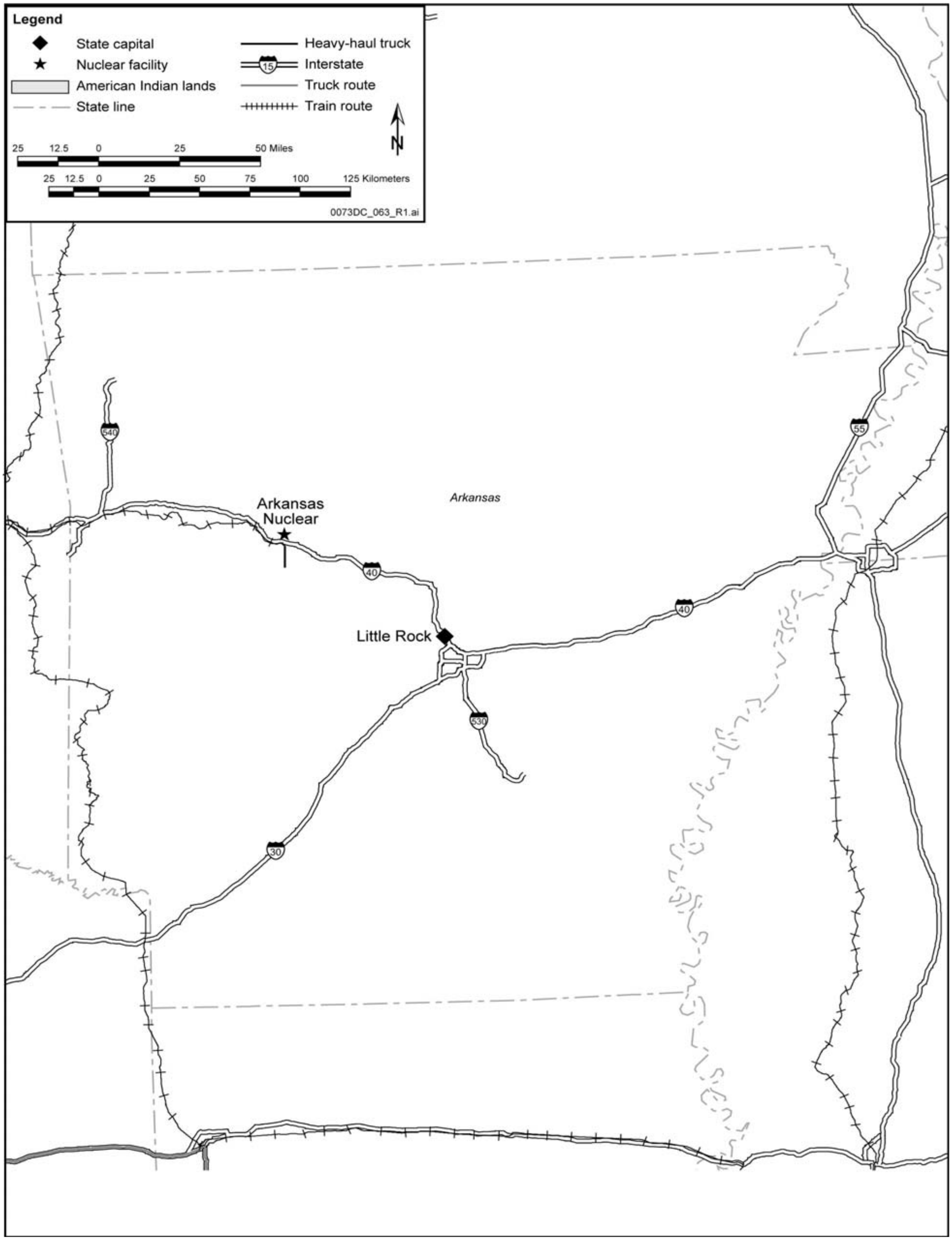

Figure G-5. Representative transportation routes for the State of Arkansas.

Table G-25. Estimated transportation impacts for the State of California.

Rail alignment	No. of Casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	755	35	82	0.021	0.049	0.042	0.16	9.9×10^{-5}	0.032	0.14
Truck	857	7.6	24	0.0045	0.015	0.0010	3.1×10^{-4}	1.9×10^{-7}	0.015	0.036
Total	1,612	43	110	0.026	0.064	0.043	0.16	9.9×10^{-5}	0.047	0.18
Mina										
Rail	1,963	99	160	0.059	0.098	0.12	0.35	2.1×10^{-4}	0.087	0.36
Truck	857	7.6	24	0.0045	0.015	0.0010	3.1×10^{-4}	1.9×10^{-7}	0.015	0.036
Total	2,820	110	190	0.064	0.11	0.12	0.35	2.1×10^{-4}	0.10	0.40

a. Totals might differ from sums of values due to rounding.

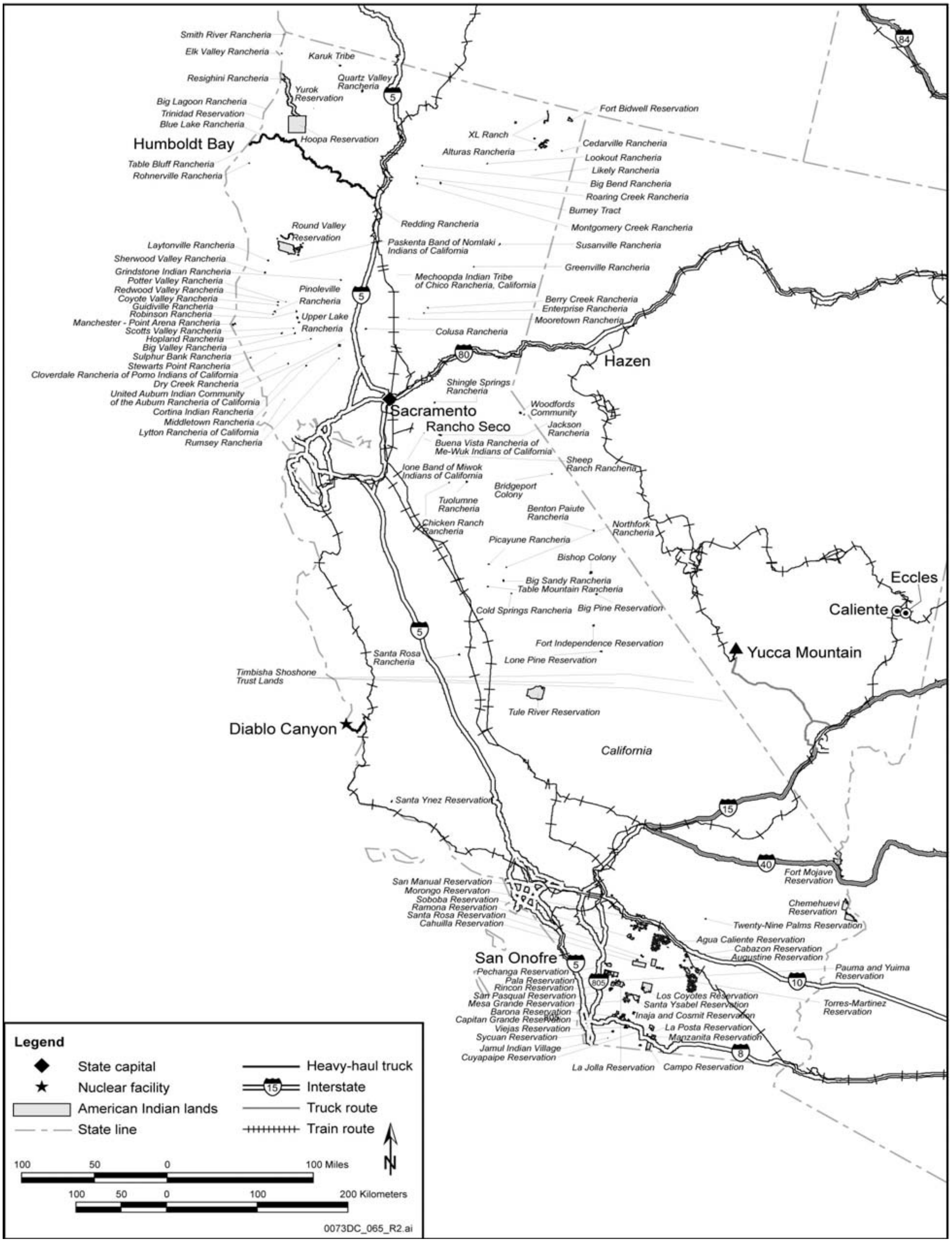

Figure G-6. Representative transportation routes for the State of California.

Table G-26. Estimated transportation impacts for the State of Colorado.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	6,739	6.8	35	0.0041	0.021	0.010	0.055	3.3×10^{-5}	0.024	0.059
Truck	0	0	0	0	0	0	0	0	0	0
Total	6,739	6.8	35	0.0041	0.021	0.010	0.055	3.3×10^{-5}	0.024	0.059
Mina										
Rail	6,838	9.4	43	0.0056	0.026	0.014	0.068	4.1×10^{-5}	0.029	0.075
Truck	0	0	0	0	0	0	0	0	0	0
Total	6,838	9.4	43	0.0056	0.026	0.014	0.068	4.1×10^{-5}	0.029	0.075

a. Totals might differ from sums of values due to rounding.

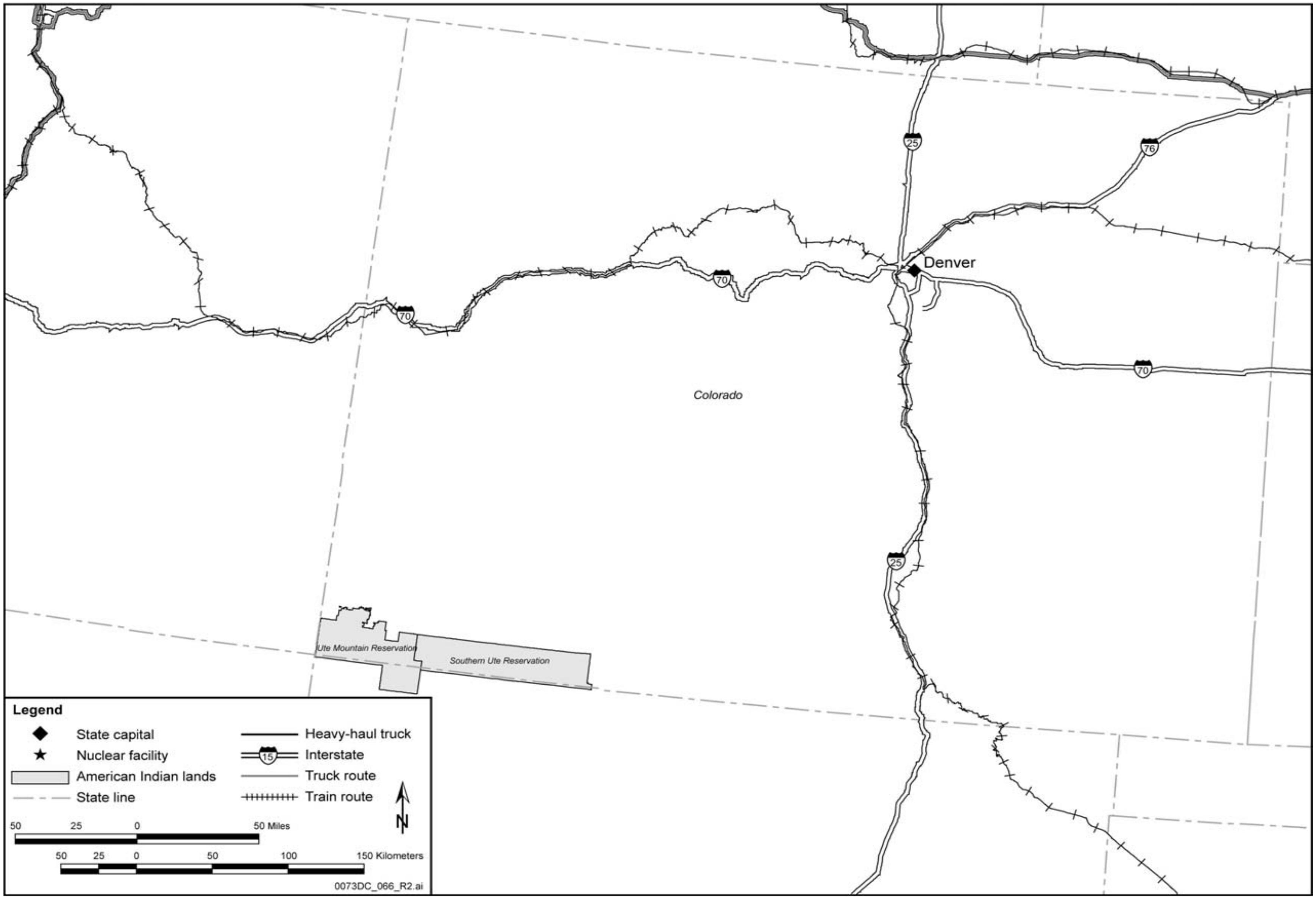

Figure G-7. Representative transportation routes for the State of Colorado.

Table G-27. Estimated transportation impacts for the State of Connecticut.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	216	1.5	19	9.2×10^{-4}	0.012	0.0017	0.0073	4.4×10^{-6}	0.0015	0.016
Truck	344	3.6	3.7	0.0022	0.0022	0.0018	0.0030	1.8×10^{-6}	0.0036	0.0098
Total	560	5.2	23	0.0031	0.014	0.0035	0.010	6.2×10^{-6}	0.0050	0.025
Mina										
Rail	216	1.5	19	9.2×10^{-4}	0.012	0.0017	0.0073	4.4×10^{-6}	0.0015	0.016
Truck	344	3.6	3.7	0.0022	0.0022	0.0018	0.0030	1.8×10^{-6}	0.0036	0.0098
Total	560	5.2	23	0.0031	0.014	0.0035	0.010	6.2×10^{-6}	0.0050	0.025

a. Totals might differ from sums of values due to rounding.

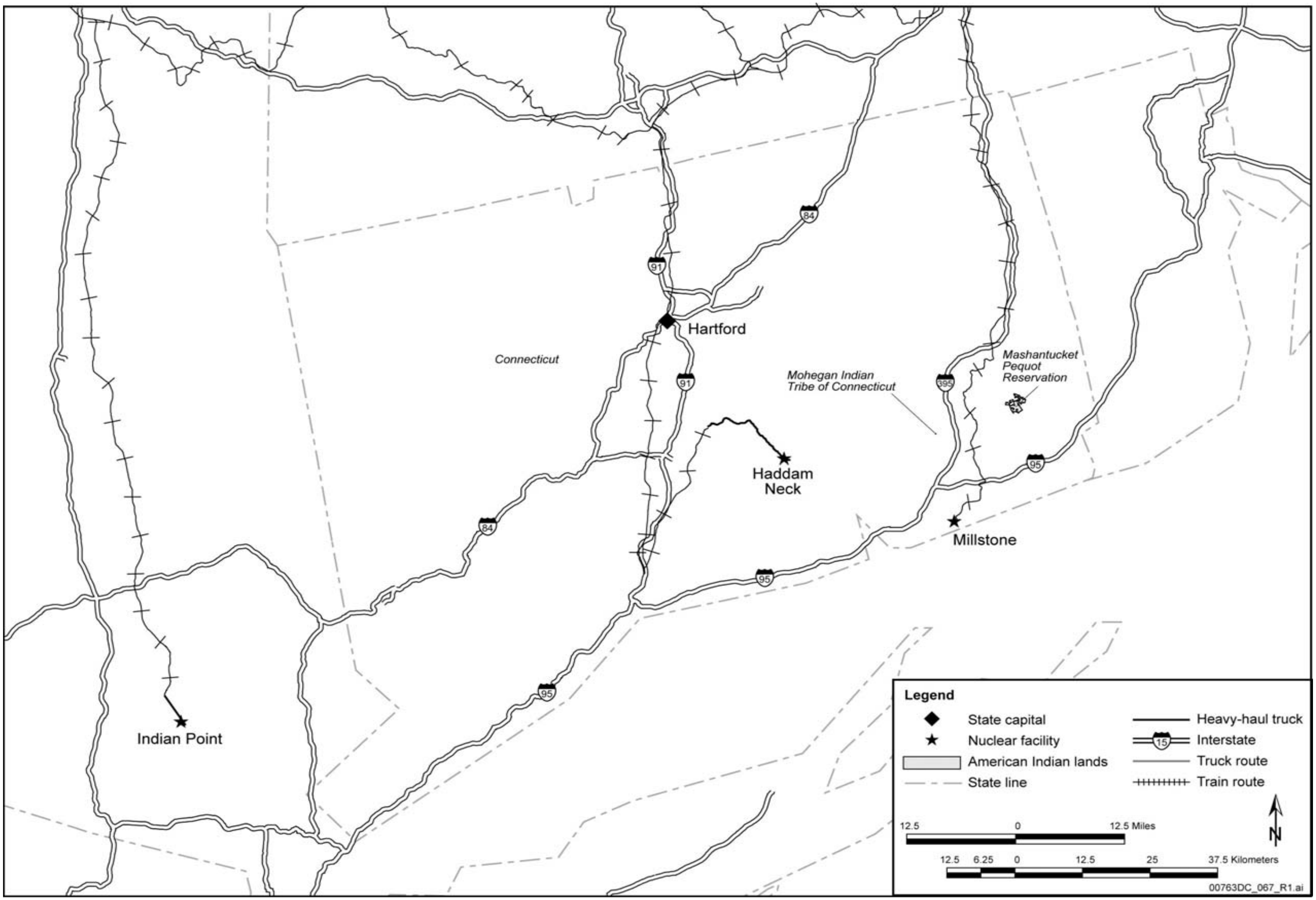

Figure G-8. Representative transportation routes for the State of Connecticut.

Table G-28. Estimated transportation impacts for the District of Columbia.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	255	1.2	0.89	7.0×10^{-4}	5.3×10^{-4}	0.0014	0.0052	3.1×10^{-6}	3.5×10^{-4}	0.0030
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	1.2	0.89	7.0×10^{-4}	5.3×10^{-4}	0.0014	0.0052	3.1×10^{-6}	3.5×10^{-4}	0.0030
Mina										
Rail	255	1.2	0.89	7.0×10^{-4}	5.3×10^{-4}	0.0014	0.0052	3.1×10^{-6}	3.5×10^{-4}	0.0030
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	1.2	0.89	7.0×10^{-4}	5.3×10^{-4}	0.0014	0.0052	3.1×10^{-6}	3.5×10^{-4}	0.0030

a. Totals might differ from sums of values due to rounding.

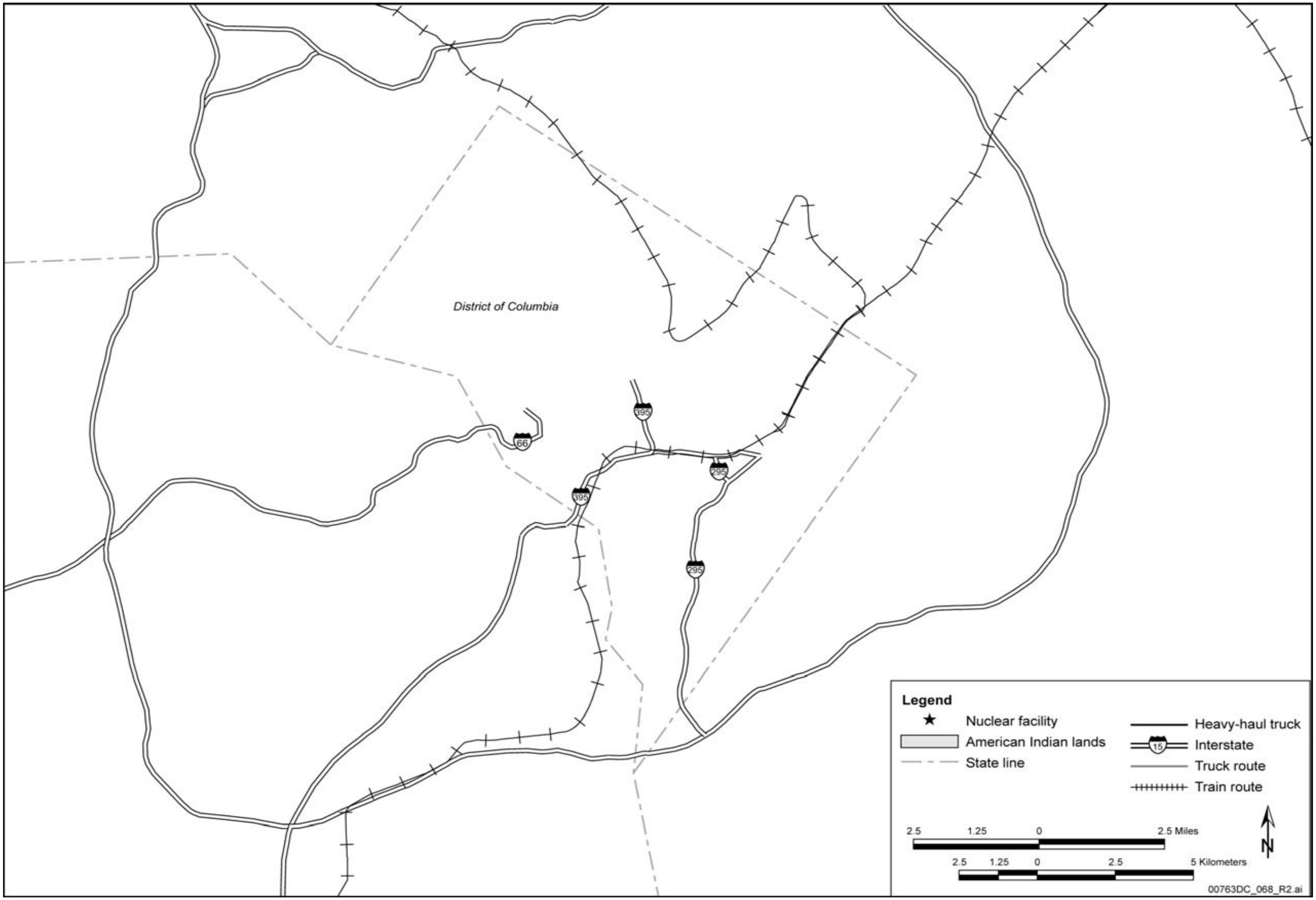

Figure G-9. Representative transportation routes for the District of Columbia.

Table G-29. Estimated transportation impacts for the State of Florida.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	138	13	31	0.0078	0.019	0.013	0.047	2.8×10^{-5}	0.0039	0.043
Truck	857	47	100	0.028	0.060	0.032	0.0040	2.4×10^{-6}	0.040	0.16
Total	995	60	130	0.036	0.079	0.044	0.051	3.1×10^{-5}	0.044	0.20
Mina										
Rail	138	13	31	0.0078	0.019	0.013	0.047	2.8×10^{-5}	0.0039	0.043
Truck	857	47	100	0.028	0.060	0.032	0.0040	2.4×10^{-6}	0.040	0.16
Total	995	60	130	0.036	0.079	0.044	0.051	3.1×10^{-5}	0.044	0.20

a. Totals might differ from sums of values due to rounding.

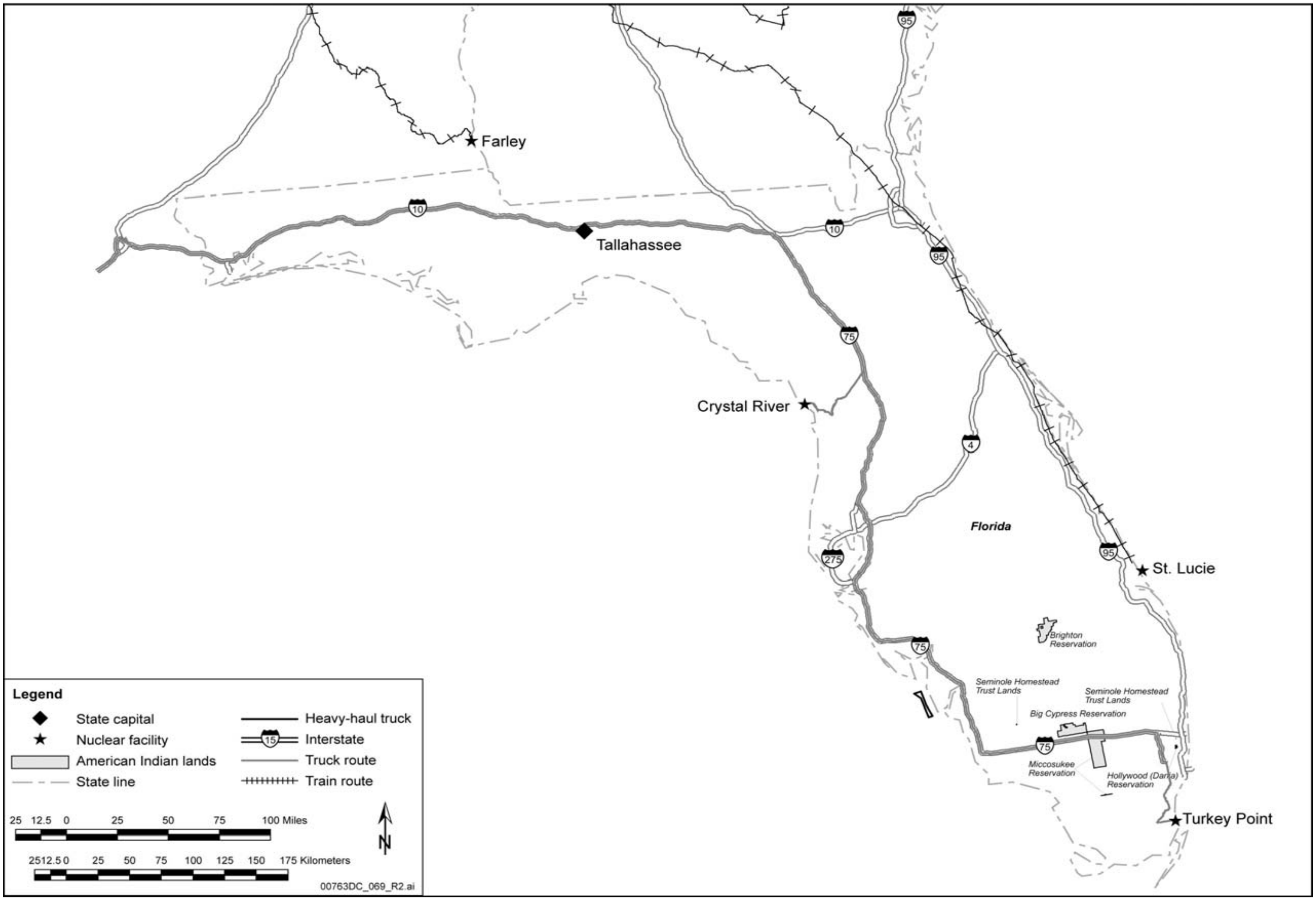

Figure G-10. Representative transportation routes for the State of Florida.

Table G-30. Estimated transportation impacts for the State of Georgia.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	1,672	53	85	0.032	0.051	0.065	0.17	1.0×10^{-4}	0.044	0.19
Truck	0	0	0	0	0	0	0	0	0	0
Total	1,672	53	85	0.032	0.051	0.065	0.17	1.0×10^{-4}	0.044	0.19
Mina										
Rail	1,672	53	85	0.032	0.051	0.065	0.17	1.0×10^{-4}	0.044	0.19
Truck	0	0	0	0	0	0	0	0	0	0
Total	1,672	53	85	0.032	0.051	0.065	0.17	1.0×10^{-4}	0.044	0.19

a. Totals might differ from sums of values due to rounding.

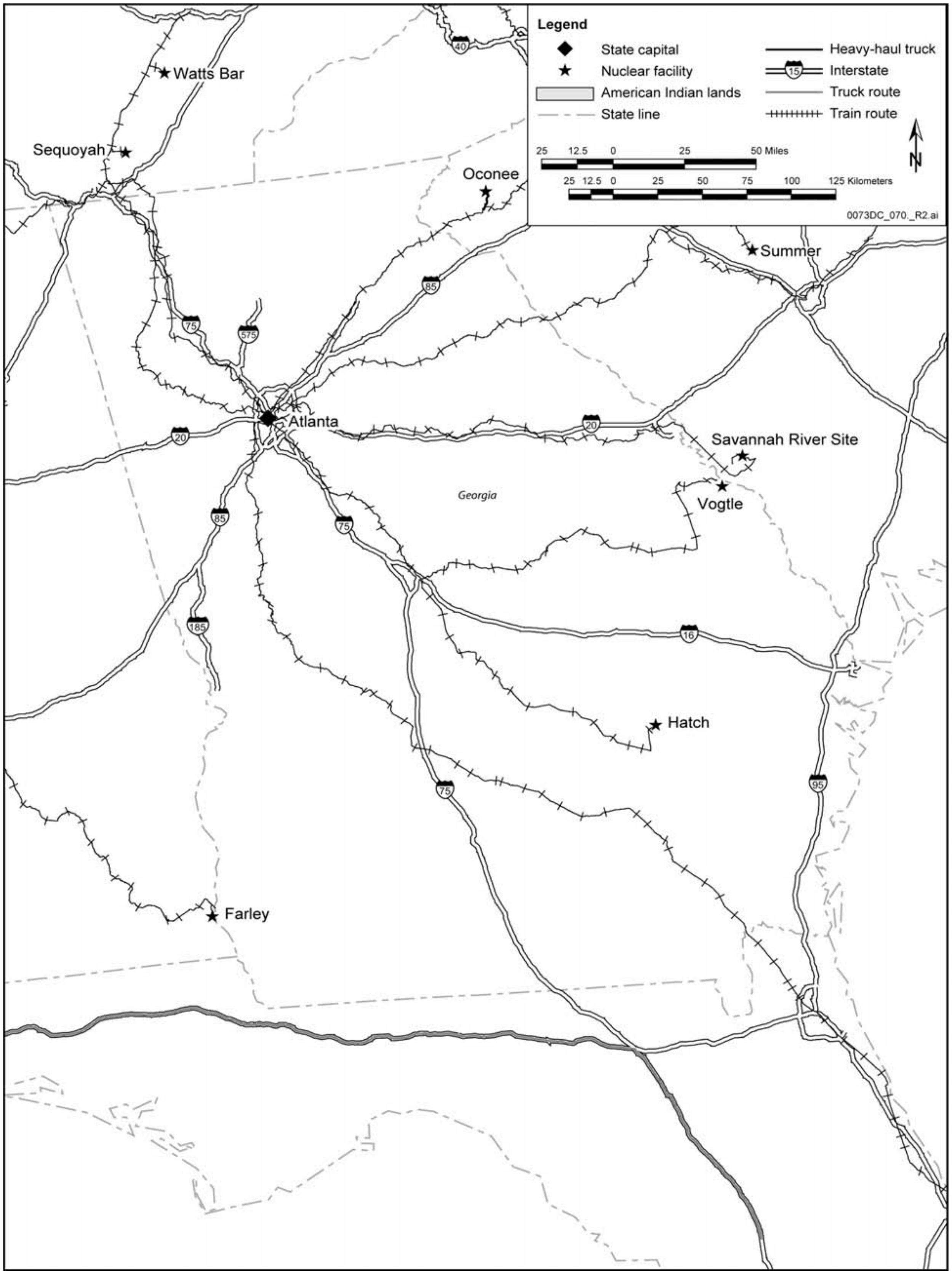

Figure G-11. Representative transportation routes for the State of Georgia.

Table G-31. Estimated transportation impacts for the State of Idaho.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	2,001	28	310	0.017	0.19	0.021	0.015	9.1×10^{-6}	0.046	0.27
Truck	4	0.046	0.15	2.8×10^{-5}	9.0×10^{-5}	1.7×10^{-5}	9.0×10^{-6}	5.4×10^{-9}	5.0×10^{-5}	1.8×10^{-4}
Total	2,005	28	310	0.017	0.19	0.021	0.015	9.1×10^{-6}	0.046	0.27
Mina										
Rail	694	13	270	0.0080	0.16	0.0043	0.0017	1.0×10^{-6}	0.0077	0.18
Truck	4	0.046	0.15	2.8×10^{-5}	9.0×10^{-5}	1.7×10^{-5}	9.0×10^{-6}	5.4×10^{-9}	5.0×10^{-5}	1.8×10^{-4}
Total	698	13	270	0.0080	0.16	0.0044	0.0017	1.0×10^{-6}	0.0077	0.18

a. Totals might differ from sums of values due to rounding.

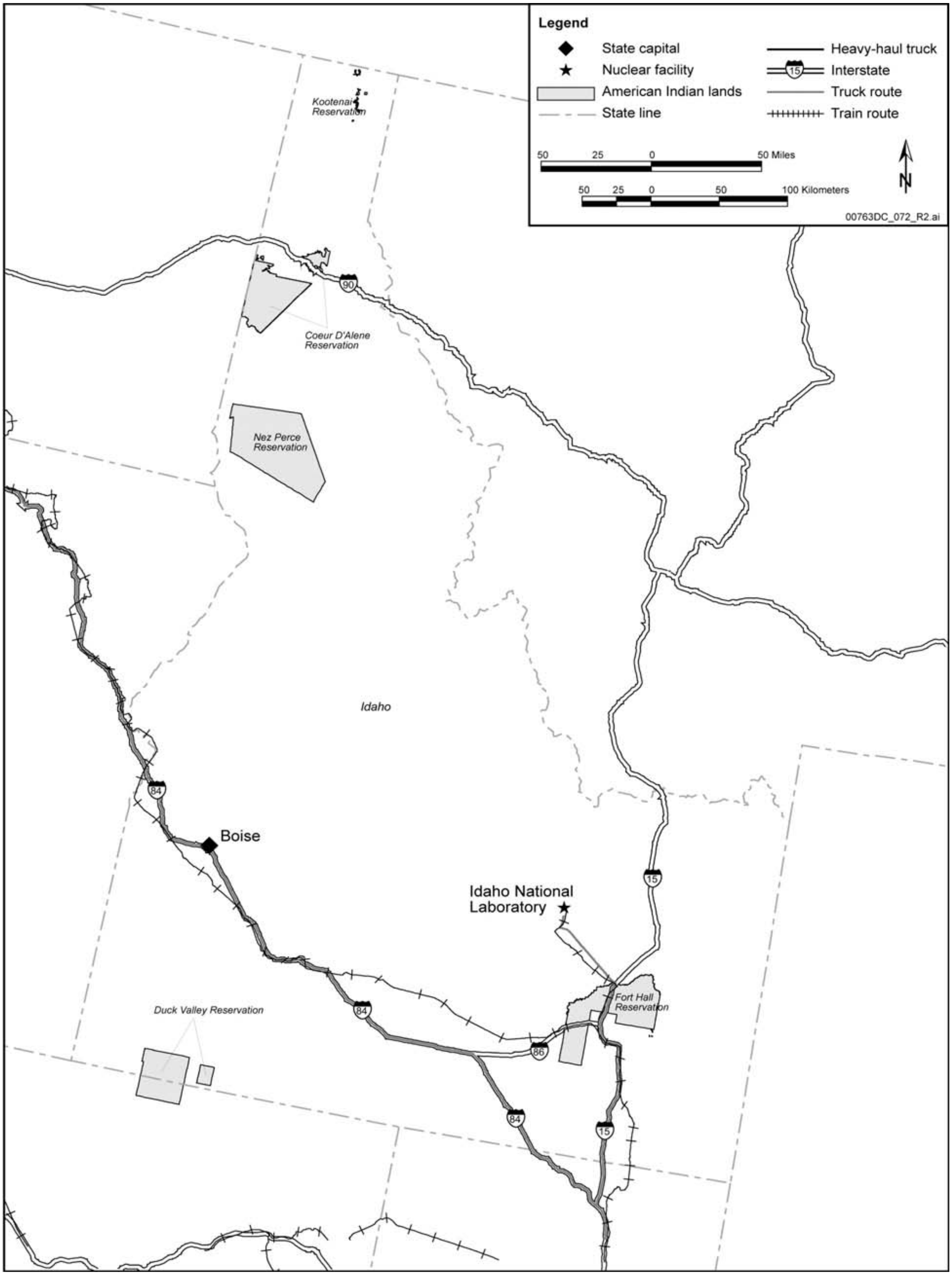

Figure G-12. Representative transportation routes for the State of Idaho.

Table G-32. Estimated transportation impacts for the State of Illinois.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	6,069	75	200	0.045	0.12	0.094	0.47	2.8×10^{-4}	0.091	0.35
Truck	1,752	15	46	0.0090	0.028	0.0044	0.0020	1.2×10^{-6}	0.021	0.062
Total	7,821	90	250	0.054	0.15	0.099	0.47	2.8×10^{-4}	0.11	0.41
Mina										
Rail	6,069	75	200	0.045	0.12	0.094	0.47	2.8×10^{-4}	0.091	0.35
Truck	1,752	15	46	0.0090	0.028	0.0044	0.0020	1.2×10^{-6}	0.021	0.062
Total	7,821	90	250	0.054	0.15	0.099	0.47	2.8×10^{-4}	0.11	0.41

a. Totals might differ from sums of values due to rounding.

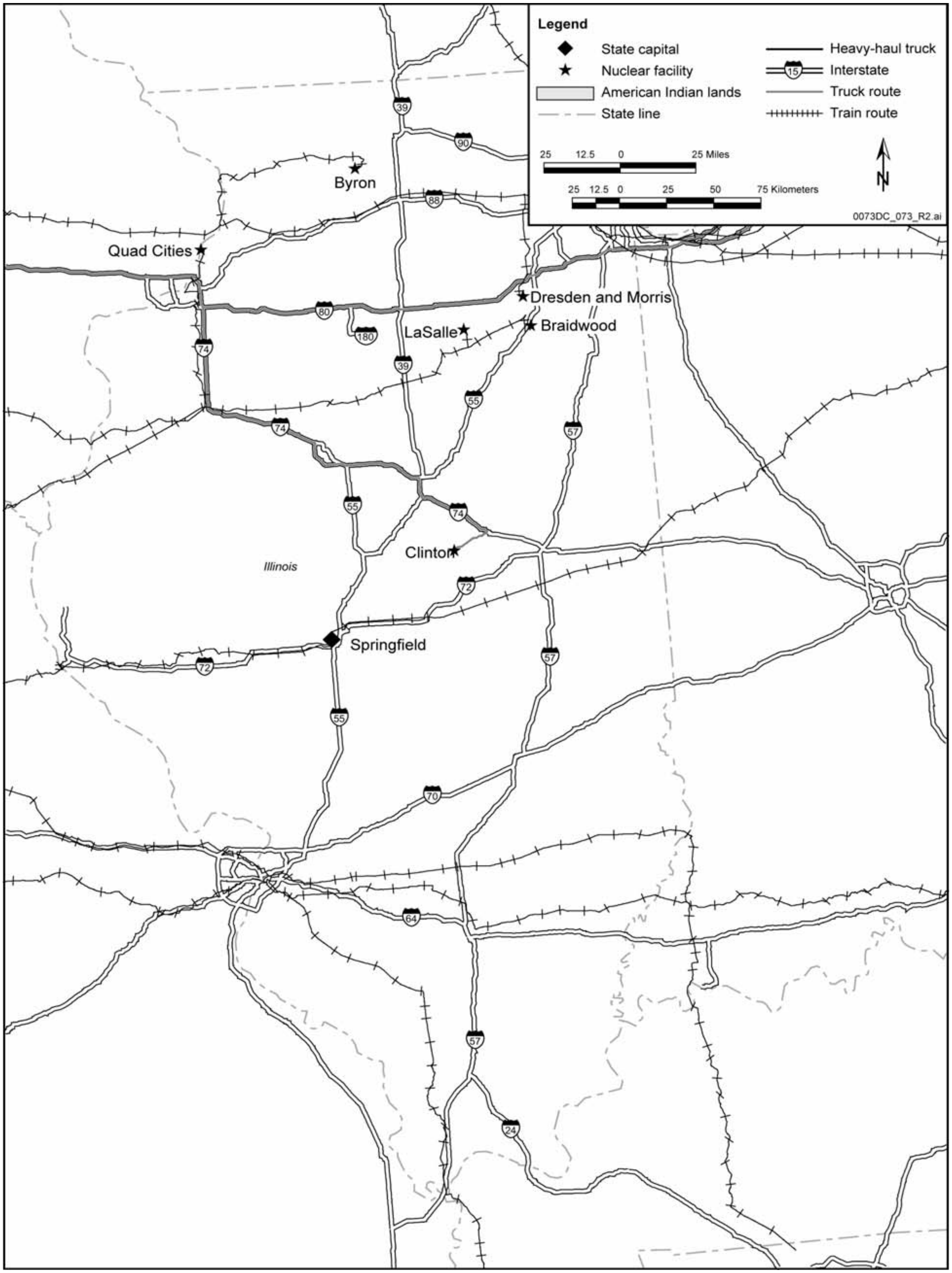

Figure G-13. Representative transportation routes for the State of Illinois.

Table G-33. Estimated transportation impacts for the State of Indiana.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	4,887	27	86	0.016	0.052	0.036	0.18	1.1×10^{-4}	0.055	0.16
Truck	1,425	9.1	15	0.0055	0.0088	0.0035	0.0015	9.0×10^{-7}	0.0089	0.027
Total	6,312	36	100	0.021	0.061	0.039	0.19	1.1×10^{-4}	0.064	0.19
Mina										
Rail	4,887	27	86	0.016	0.052	0.036	0.18	1.1×10^{-4}	0.055	0.16
Truck	1,425	9.1	15	0.0055	0.0088	0.0035	0.0015	9.0×10^{-7}	0.0089	0.027
Total	6,312	36	100	0.021	0.061	0.039	0.19	1.1×10^{-4}	0.064	0.19

a. Totals might differ from sums of values due to rounding.

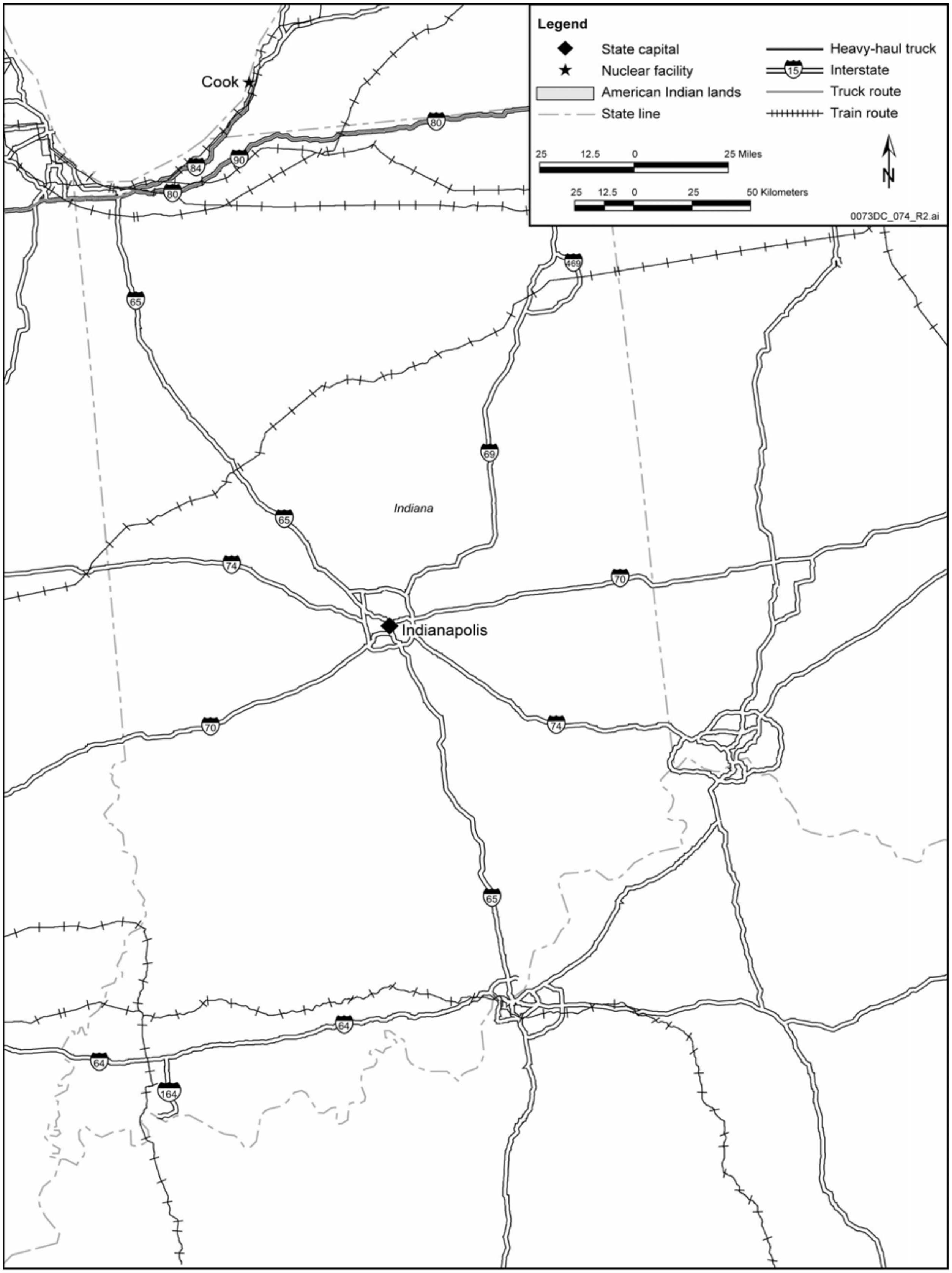

Figure G-14. Representative transportation routes for the State of Indiana.

Table G-34. Estimated transportation impacts for the State of Iowa.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	3,066	13	150	0.0079	0.089	0.020	0.19	1.2×10^{-4}	0.096	0.21
Truck	1,789	22	59	0.013	0.035	0.0037	0.0011	6.5×10^{-7}	0.044	0.096
Total	4,855	35	210	0.021	0.12	0.023	0.19	1.2×10^{-4}	0.14	0.31
Mina										
Rail	3,066	13	150	0.0079	0.089	0.020	0.19	1.2×10^{-4}	0.096	0.21
Truck	1,789	22	59	0.013	0.035	0.0037	0.0011	6.5×10^{-7}	0.044	0.096
Total	4,855	35	210	0.021	0.12	0.023	0.19	1.2×10^{-4}	0.14	0.31

a. Totals might differ from sums of values due to rounding.

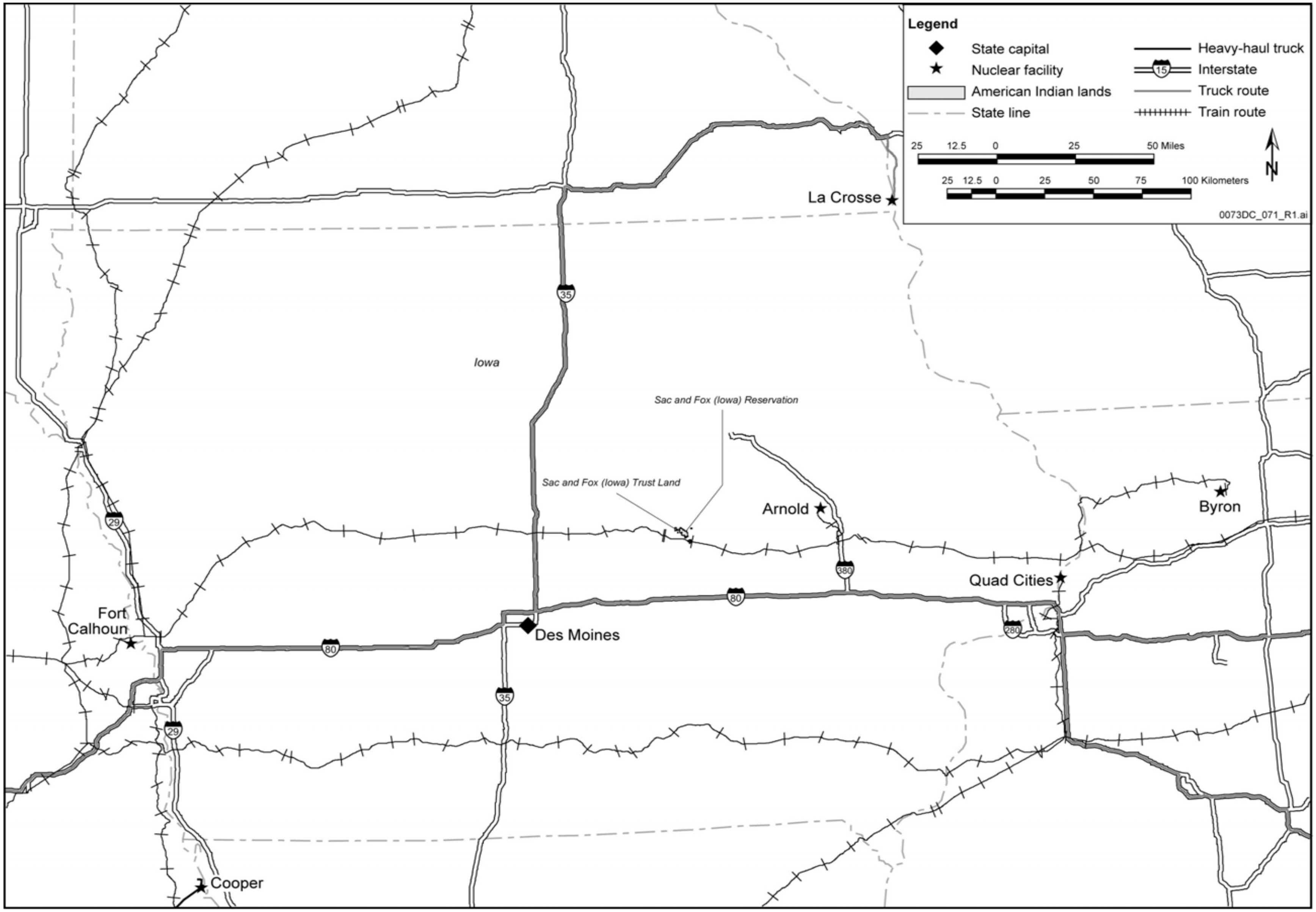

Figure G-15. Representative transportation routes for the State of Iowa.

Table G-35. Estimated transportation impacts for the State of Kansas.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	3,574	8.7	90	0.0052	0.054	0.012	0.066	3.9×10^{-5}	0.061	0.13
Truck	0	0	0	0	0	0	0	0	0	0
Total	3,574	8.7	90	0.0052	0.054	0.012	0.066	3.9×10^{-5}	0.061	0.13
Mina										
Rail	3,574	8.7	90	0.0052	0.054	0.012	0.066	3.9×10^{-5}	0.061	0.13
Truck	0	0	0	0	0	0	0	0	0	0
Total	3,574	8.7	90	0.0052	0.054	0.012	0.066	3.9×10^{-5}	0.061	0.13

a. Totals might differ from sums of values due to rounding.

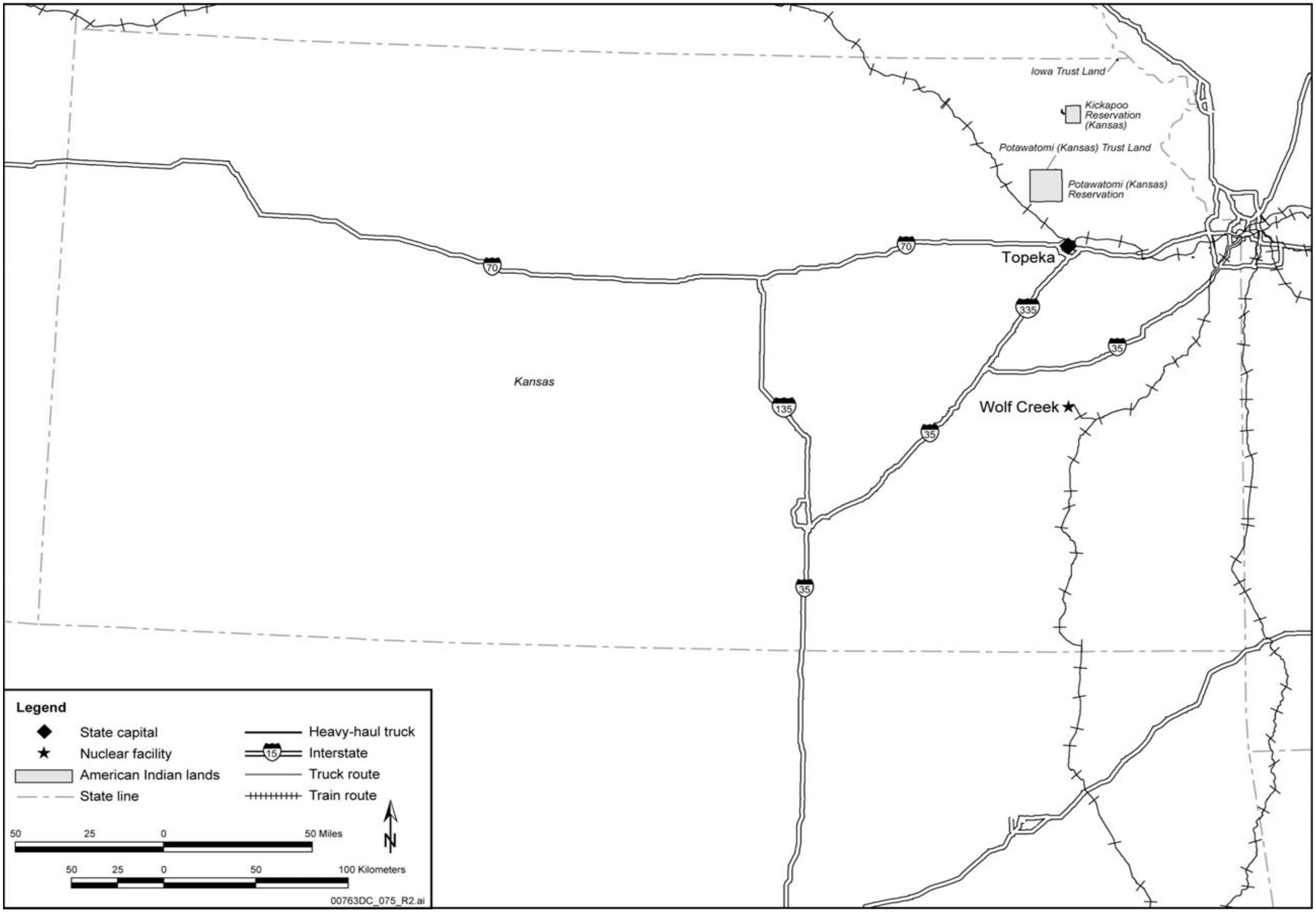

Figure G-16. Representative transportation routes for the State of Kansas.

Table G-36. Estimated transportation impacts for the Commonwealth of Kentucky.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	2,663	14	50	0.0086	0.030	0.020	0.077	4.6×10^{-5}	0.032	0.090
Truck	0	0	0	0	0	0	0	0	0	0
Total	2,663	14	50	0.0086	0.030	0.020	0.077	4.6×10^{-5}	0.032	0.090
Mina										
Rail	2,663	14	50	0.0086	0.030	0.020	0.077	4.6×10^{-5}	0.032	0.090
Truck	0	0	0	0	0	0	0	0	0	0
Total	2,663	14	50	0.0086	0.030	0.020	0.077	4.6×10^{-5}	0.032	0.090

a. Totals might differ from sums of values due to rounding.

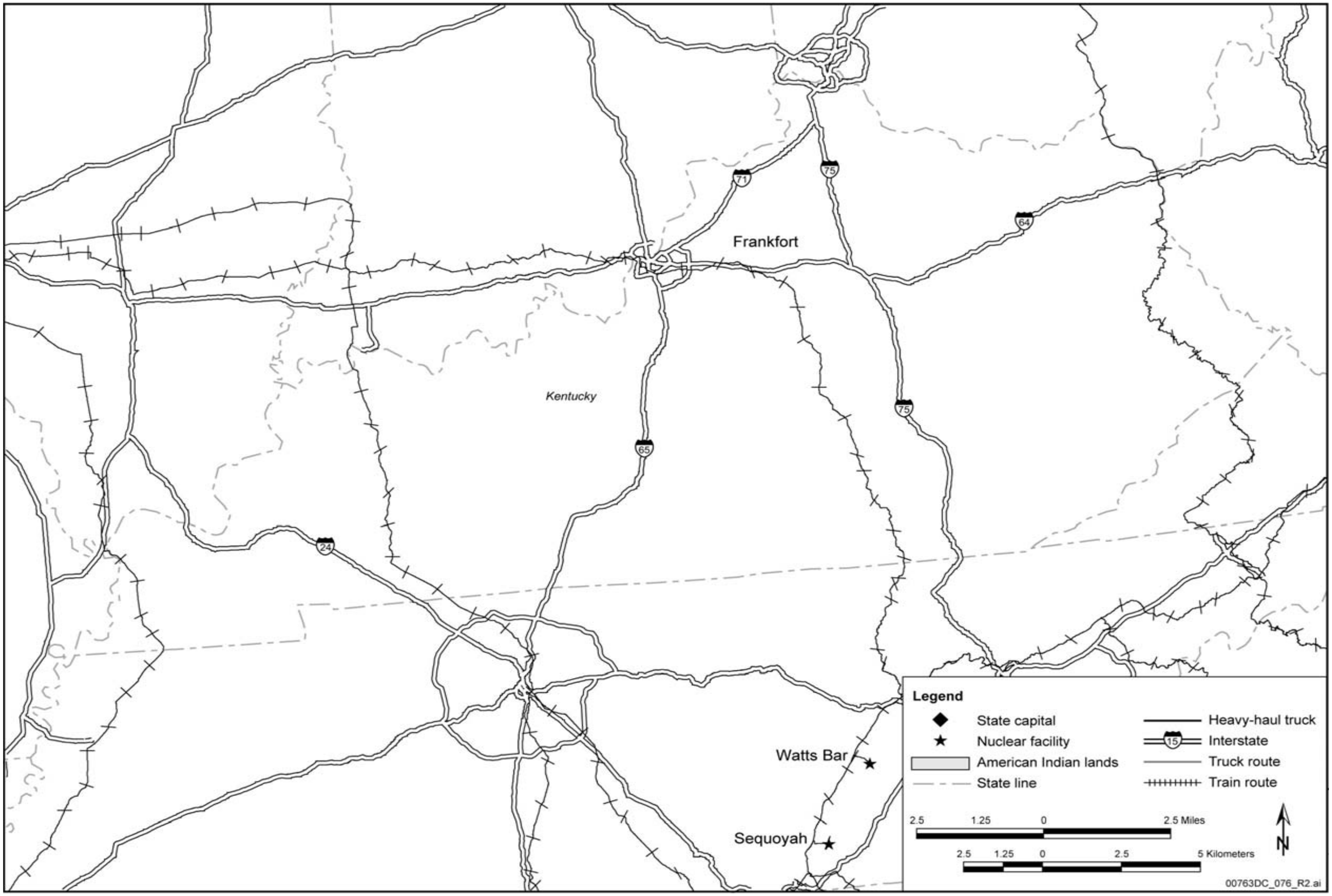

Figure G-17. Representative transportation routes for the Commonwealth of Kentucky.

Table G-37. Estimated transportation impacts for the State of Louisiana.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	233	1.3	14	7.8×10^{-4}	0.0082	0.0019	0.0098	5.9×10^{-6}	0.0043	0.015
Truck	857	17	35	0.010	0.021	0.0054	0.0022	1.3×10^{-6}	0.025	0.062
Total	1,090	19	48	0.011	0.029	0.0073	0.012	7.2×10^{-6}	0.029	0.077
Mina										
Rail	233	1.3	14	7.8×10^{-4}	0.0082	0.0019	0.0098	5.9×10^{-6}	0.0043	0.015
Truck	857	17	35	0.010	0.021	0.0054	0.0022	1.3×10^{-6}	0.025	0.062
Total	1,090	19	48	0.011	0.029	0.0073	0.012	7.2×10^{-6}	0.029	0.077

a. Totals might differ from sums of values due to rounding.

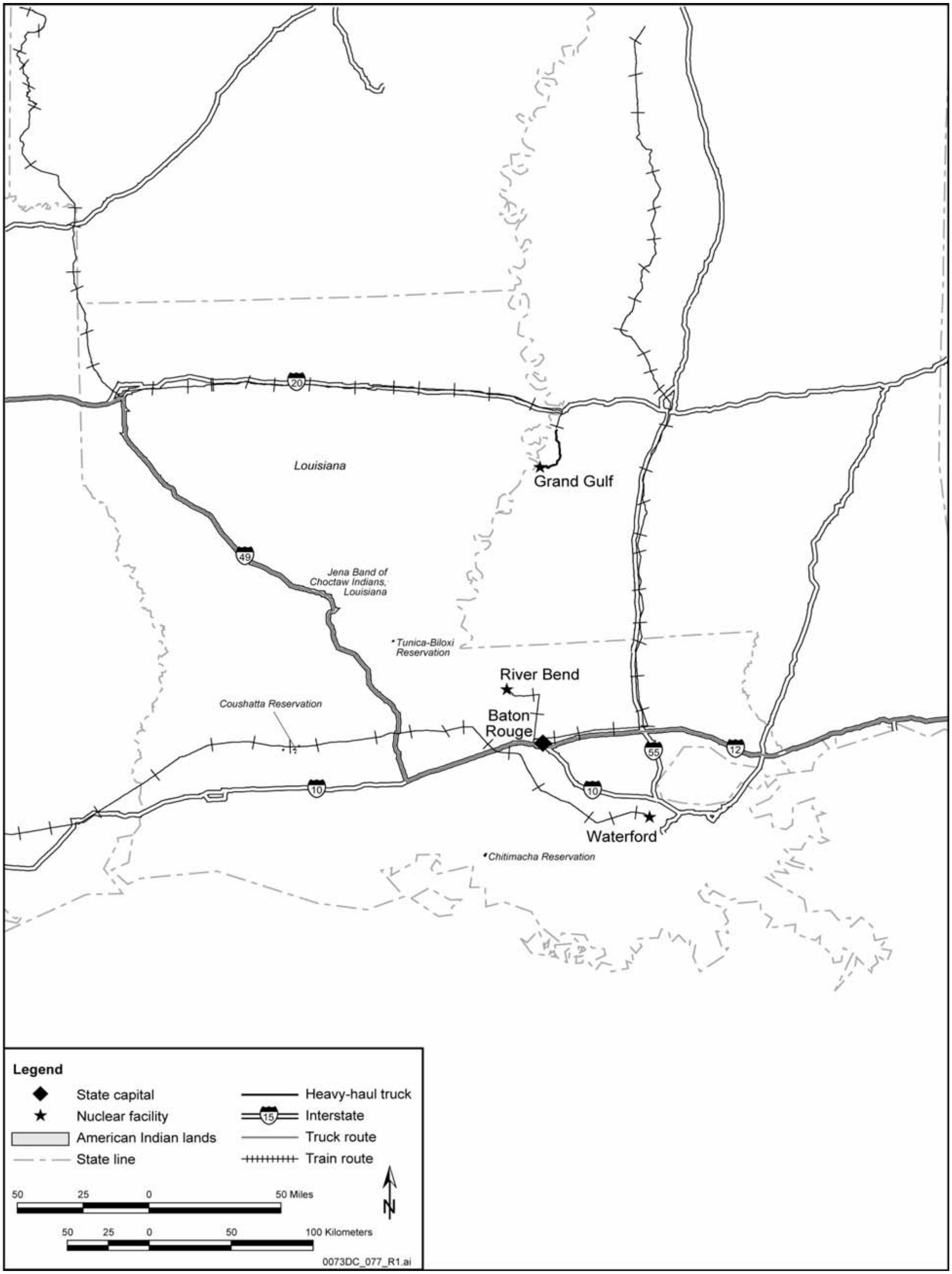

Figure G-18. Representative transportation routes for the State of Louisiana.

Table G-38. Estimated transportation impacts for the State of Maine.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	60	0.38	4.1	2.3×10^{-4}	0.0025	5.0×10^{-4}	0.0021	1.3×10^{-6}	5.3×10^{-4}	0.0037
Truck	0	0	0	0	0	0	0	0	0	0
Total	60	0.38	4.1	2.3×10^{-4}	0.0025	5.0×10^{-4}	0.0021	1.3×10^{-6}	5.3×10^{-4}	0.0037
Mina										
Rail	60	0.38	4.1	2.3×10^{-4}	0.0025	5.0×10^{-4}	0.0021	1.3×10^{-6}	5.3×10^{-4}	0.0037
Truck	0	0	0	0	0	0	0	0	0	0
Total	60	0.38	4.1	2.3×10^{-4}	0.0025	5.0×10^{-4}	0.0021	1.3×10^{-6}	5.3×10^{-4}	0.0037

a. Totals might differ from sums of values due to rounding.

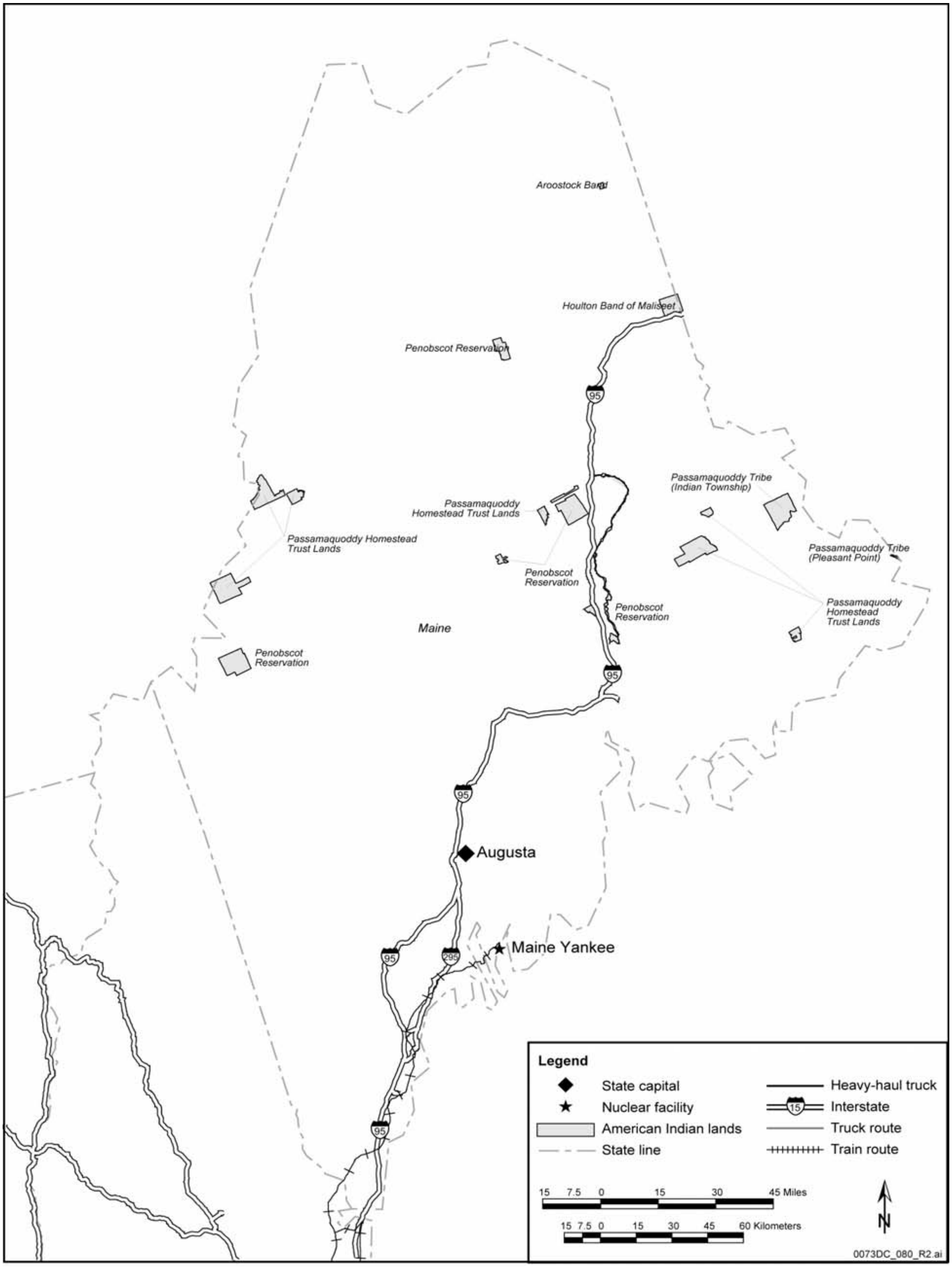

Figure G-19. Representative transportation routes for the State of Maine.

Table G-39. Estimated transportation impacts for the State of Maryland.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	255	7.9	30	0.0047	0.018	0.0075	0.029	1.8×10^{-5}	0.0039	0.034
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	7.9	30	0.0047	0.018	0.0075	0.029	1.8×10^{-5}	0.0039	0.034
Mina										
Rail	255	7.9	30	0.0047	0.018	0.0075	0.029	1.8×10^{-5}	0.0039	0.034
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	7.9	30	0.0047	0.018	0.0075	0.029	1.8×10^{-5}	0.0039	0.034

a. Totals might differ from sums of values due to rounding.

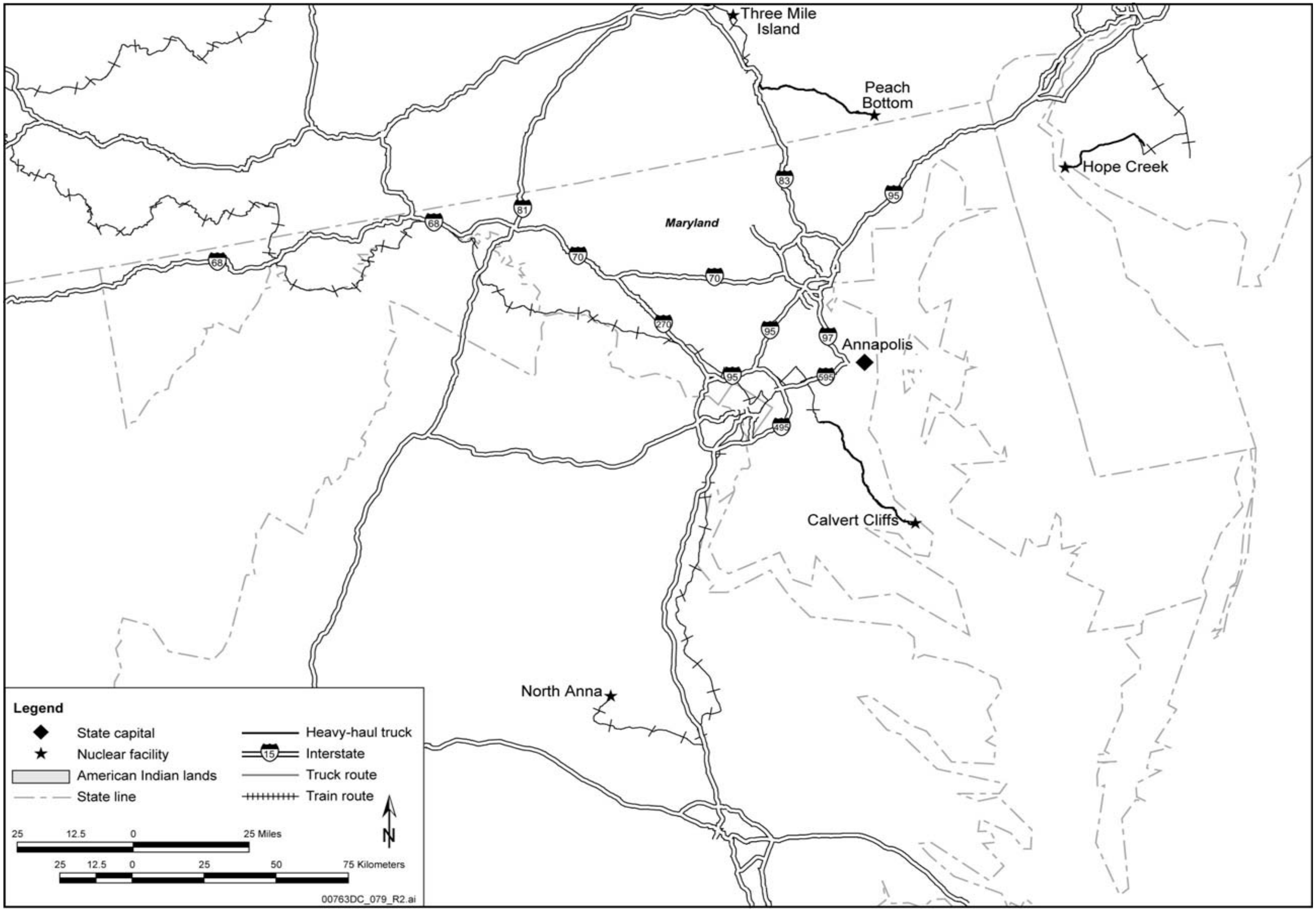

Figure G-20. Representative transportation routes for the State of Maryland.

Table G-40. Estimated transportation impacts for the Commonwealth of Massachusetts.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	415	4.8	12	0.0029	0.0071	0.0064	0.028	1.7×10^{-5}	0.0053	0.022
Truck	344	2.5	19	0.0015	0.012	8.9×10^{-4}	1.4×10^{-4}	8.4×10^{-8}	0.0013	0.015
Total	759	7.3	31	0.0044	0.019	0.0072	0.028	1.7×10^{-5}	0.0066	0.037
Mina										
Rail	415	4.8	12	0.0029	0.0071	0.0064	0.028	1.7×10^{-5}	0.0053	0.022
Truck	344	2.5	19	0.0015	0.012	8.9×10^{-4}	1.4×10^{-4}	8.4×10^{-8}	0.0013	0.015
Total	759	7.3	31	0.0044	0.019	0.0072	0.028	1.7×10^{-5}	0.0066	0.037

a. Totals might differ from sums of values due to rounding.

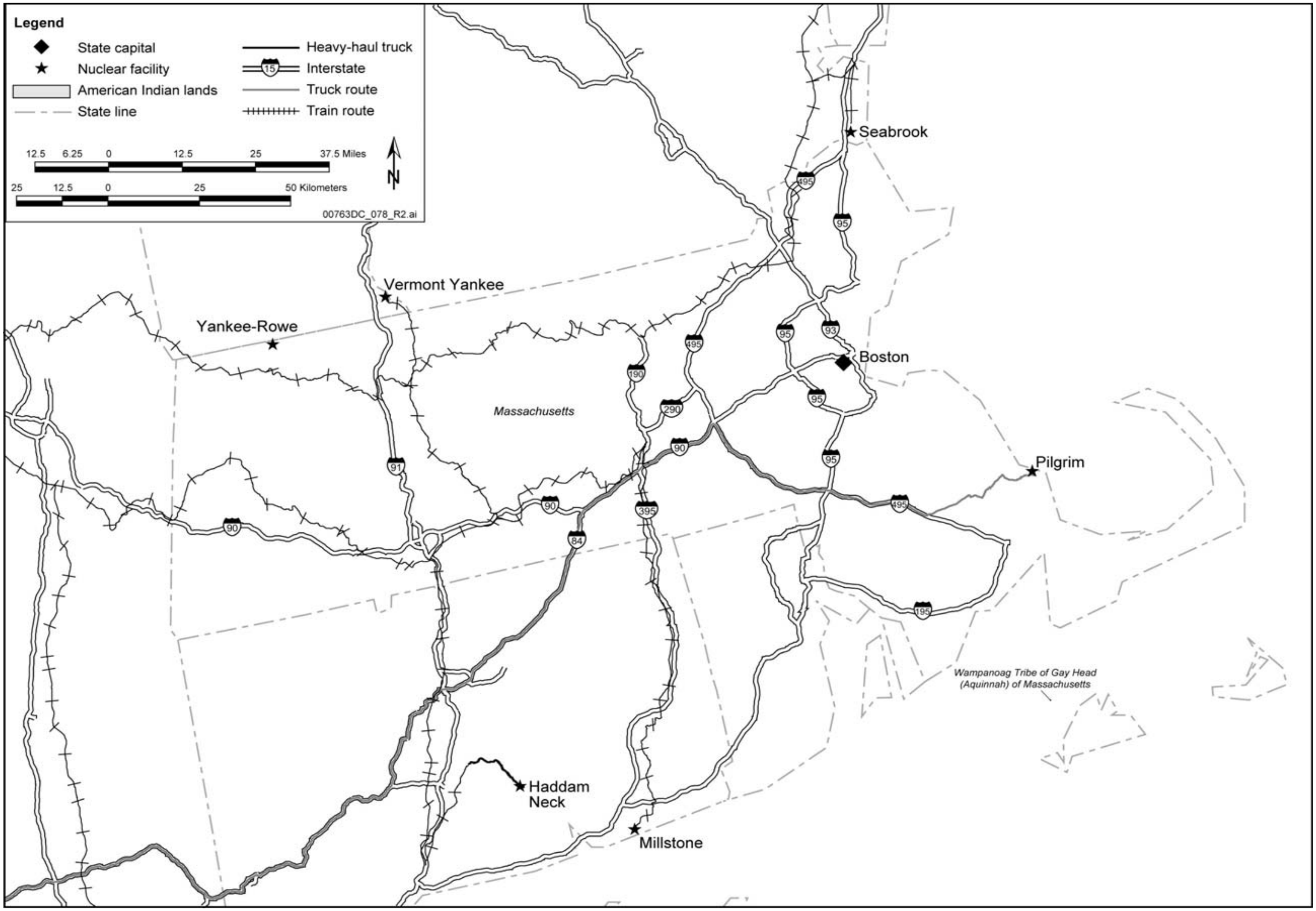

Figure G-21. Representative transportation routes for the Commonwealth of Massachusetts.

Table G-41. Estimated transportation impacts for the State of Michigan.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	132	2.3	20	0.0014	0.012	0.0023	0.013	7.8×10^{-6}	0.0025	0.018
Truck	768	0.66	37	4.0×10^{-4}	0.022	1.4×10^{-4}	7.5×10^{-5}	4.5×10^{-8}	0.0012	0.024
Total	900	2.9	57	0.0018	0.034	0.0024	0.013	7.9×10^{-6}	0.0038	0.042
Mina										
Rail	132	2.3	20	0.0014	0.012	0.0023	0.013	7.8×10^{-6}	0.0025	0.018
Truck	768	0.66	37	4.0×10^{-4}	0.022	1.4×10^{-4}	7.5×10^{-5}	4.5×10^{-8}	0.0012	0.024
Total	900	2.9	57	0.0018	0.034	0.0024	0.013	7.9×10^{-6}	0.0038	0.042

a. Totals might differ from sums of values due to rounding.

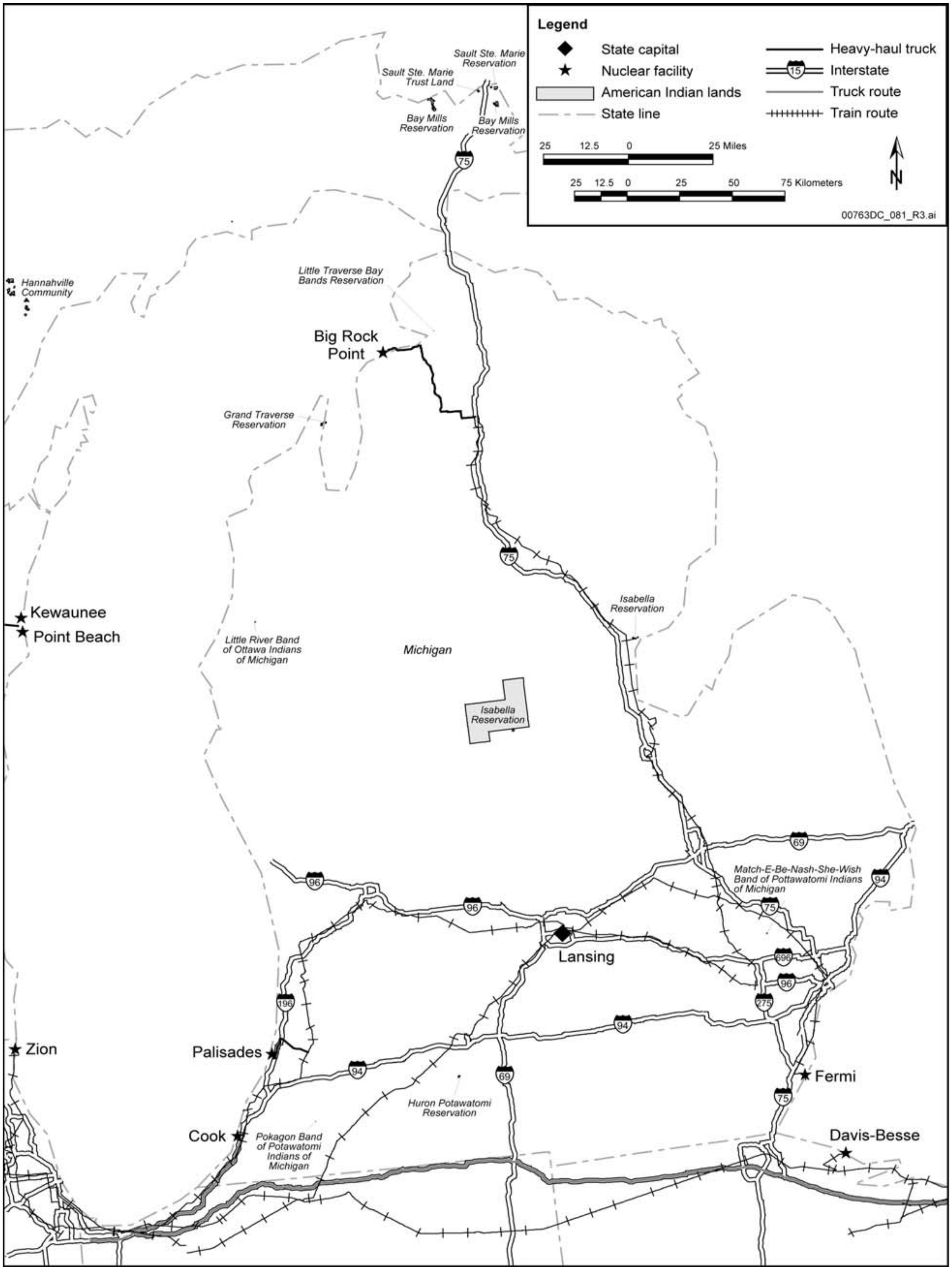

Figure G-22. Representative transportation routes for the State of Michigan.

Table G-42. Estimated transportation impacts for the State of Minnesota.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	153	1.5	14	9.0×10^{-4}	0.0083	0.0021	0.011	6.3×10^{-6}	0.0036	0.015
Truck	37	0.18	0.51	1.1×10^{-4}	3.1×10^{-4}	3.3×10^{-5}	1.2×10^{-5}	7.0×10^{-9}	2.3×10^{-4}	6.7×10^{-4}
Total	190	1.7	14	0.0010	0.0086	0.0021	0.011	6.3×10^{-6}	0.0038	0.016
Mina										
Rail	153	1.5	14	9.0×10^{-4}	0.0083	0.0021	0.011	6.3×10^{-6}	0.0036	0.015
Truck	37	0.18	0.51	1.1×10^{-4}	3.1×10^{-4}	3.3×10^{-5}	1.2×10^{-5}	7.0×10^{-9}	2.3×10^{-4}	6.7×10^{-4}
Total	190	1.7	14	0.0010	0.0086	0.0021	0.011	6.3×10^{-6}	0.0038	0.016

a. Totals might differ from sums of values due to rounding.

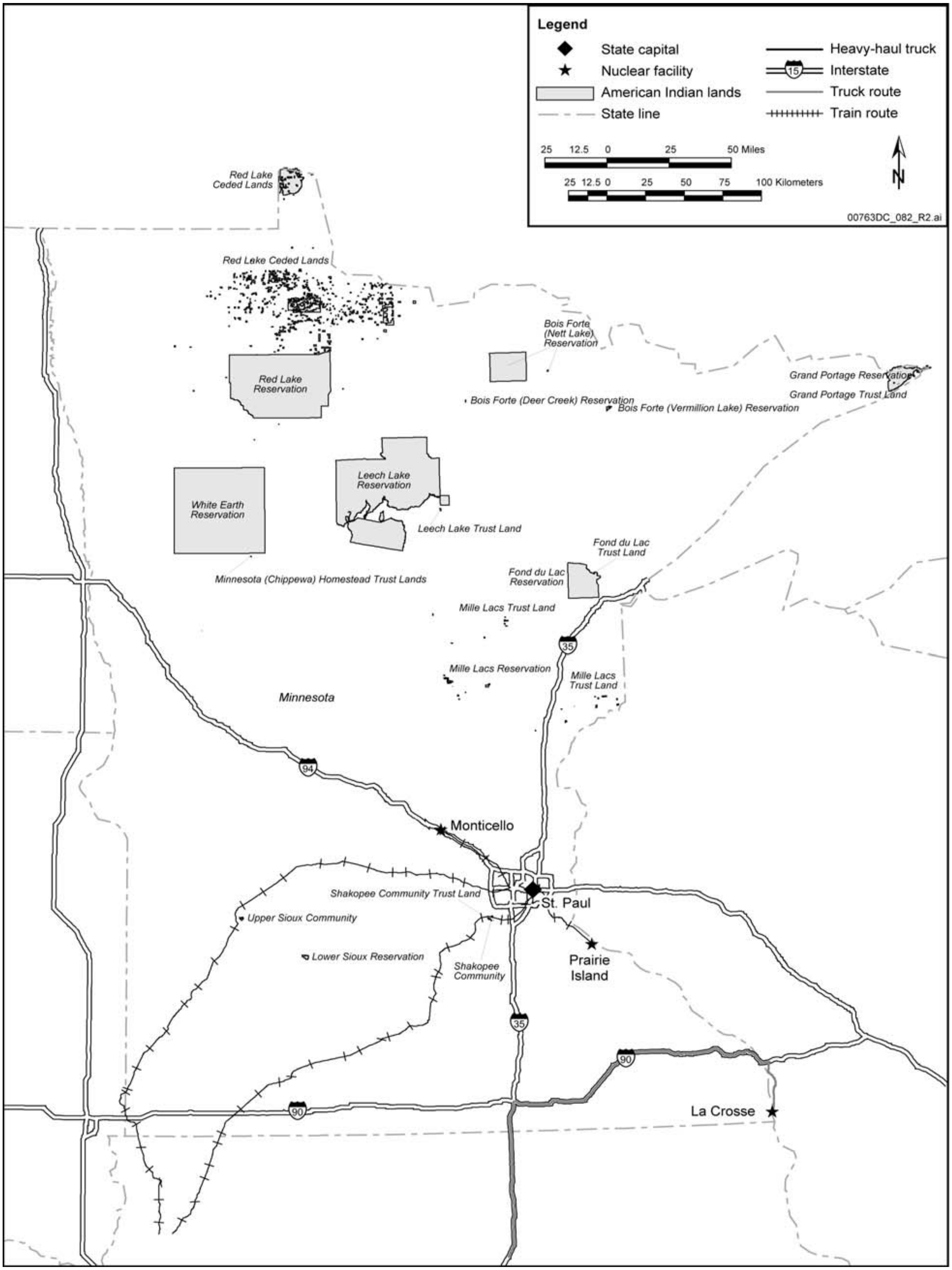

Figure G-23. Representative transportation routes for the State of Minnesota.

Table G-43. Estimated transportation impacts for the State of Mississippi.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	170	1.2	22	7.0×10^{-4}	0.013	7.4×10^{-4}	0.0042	2.5×10^{-6}	0.0026	0.017
Truck	857	3.3	7.2	0.0020	0.0043	8.5×10^{-4}	7.5×10^{-5}	4.5×10^{-8}	0.0030	0.010
Total	1,027	4.5	29	0.0027	0.017	0.0016	0.0043	2.6×10^{-6}	0.0055	0.027
Mina										
Rail	170	1.2	22	7.0×10^{-4}	0.013	7.4×10^{-4}	0.0042	2.5×10^{-6}	0.0026	0.017
Truck	857	3.3	7.2	0.0020	0.0043	8.5×10^{-4}	7.5×10^{-5}	4.5×10^{-8}	0.0030	0.010
Total	1,027	4.5	29	0.0027	0.017	0.0016	0.0043	2.6×10^{-6}	0.0055	0.027

a. Totals might differ from sums of values due to rounding.

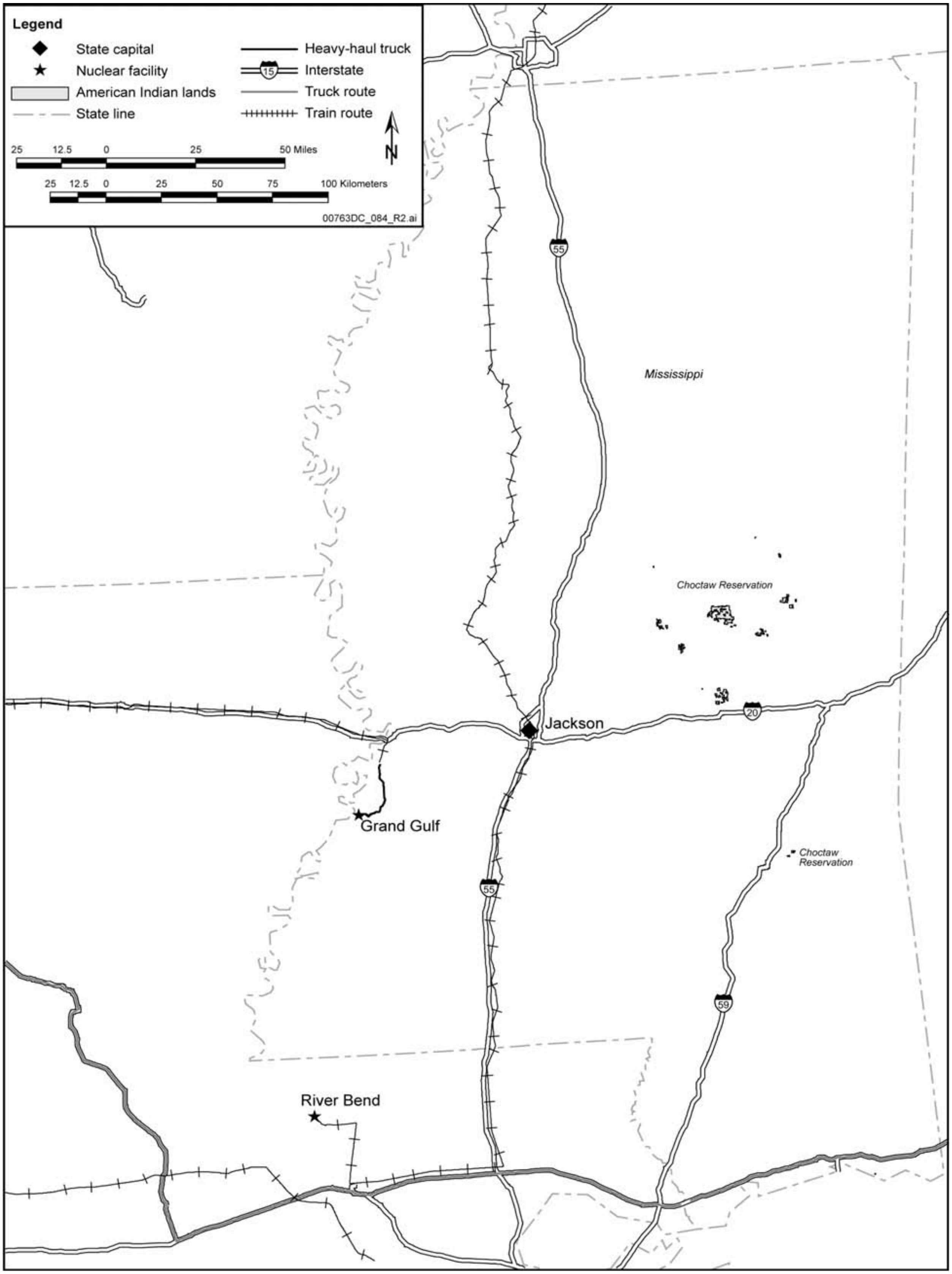

Figure G-24. Representative transportation routes for the State of Mississippi.

Table G-44. Estimated transportation impacts for the State of Missouri.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	3,574	41	140	0.024	0.083	0.052	0.19	1.2×10^{-4}	0.082	0.24
Truck	0	0	0	0	0	0	0	0	0	0
Total	3,574	41	140	0.024	0.083	0.052	0.19	1.2×10^{-4}	0.082	0.24
Mina										
Rail	3,574	41	140	0.024	0.083	0.052	0.19	1.2×10^{-4}	0.082	0.24
Truck	0	0	0	0	0	0	0	0	0	0
Total	3,574	41	140	0.024	0.083	0.052	0.19	1.2×10^{-4}	0.082	0.24

a. Totals might differ from sums of values due to rounding.

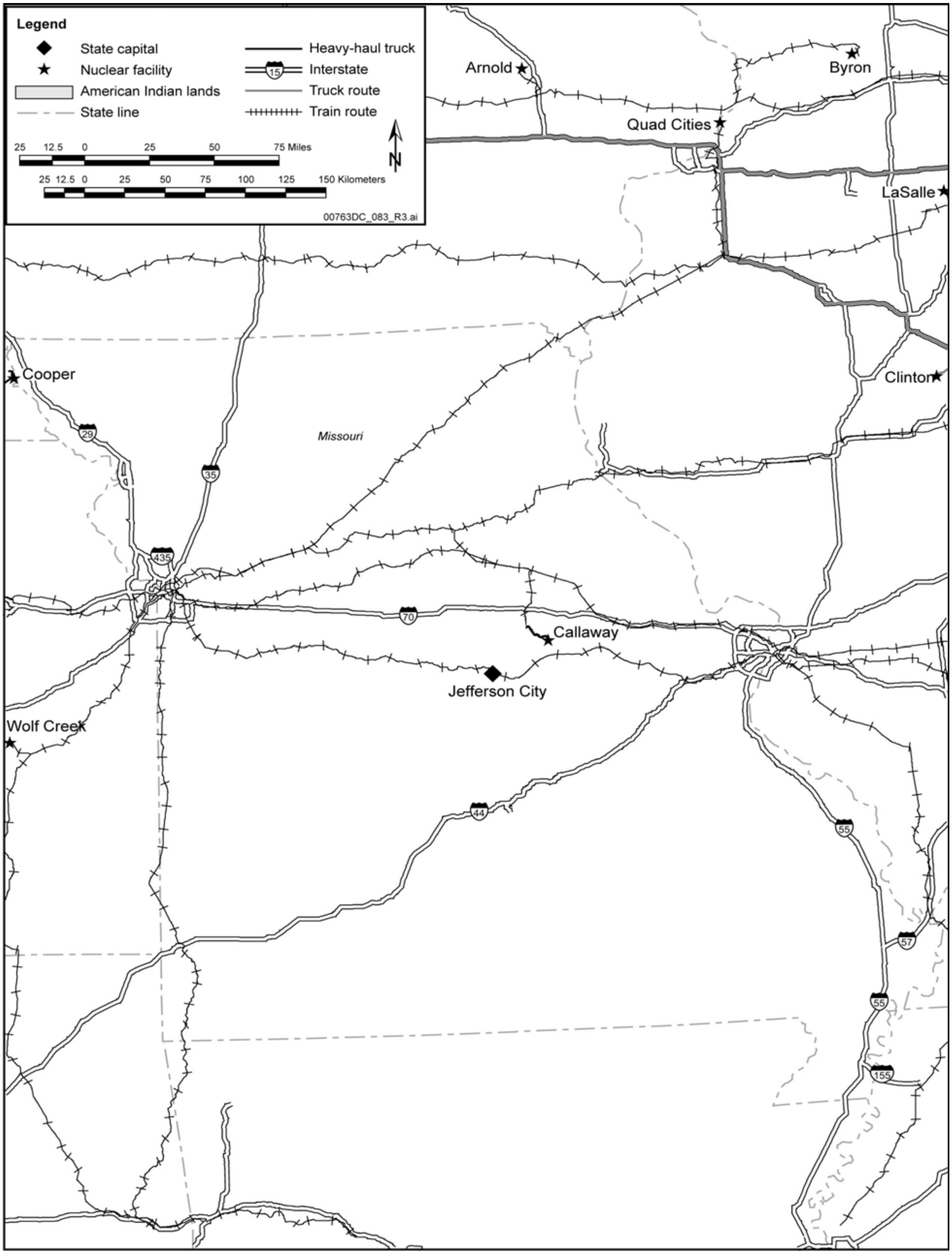

Figure G-25. Representative transportation routes for the State of Missouri.

Table G-45. Estimated transportation impacts for the State of Nebraska.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	6,739	37	400	0.022	0.24	0.052	0.35	2.1×10^{-4}	0.27	0.59
Truck	1,789	30	88	0.018	0.053	0.0042	0.0030	1.8×10^{-6}	0.083	0.16
Total	8,528	67	490	0.040	0.30	0.056	0.35	2.1×10^{-4}	0.35	0.74
Mina										
Rail	6,739	37	400	0.022	0.24	0.052	0.35	2.1×10^{-4}	0.27	0.59
Truck	1,789	30	88	0.018	0.053	0.0042	0.0030	1.8×10^{-6}	0.083	0.16
Total	8,528	67	490	0.040	0.30	0.056	0.35	2.1×10^{-4}	0.35	0.74

a. Totals might differ from sums of values due to rounding.

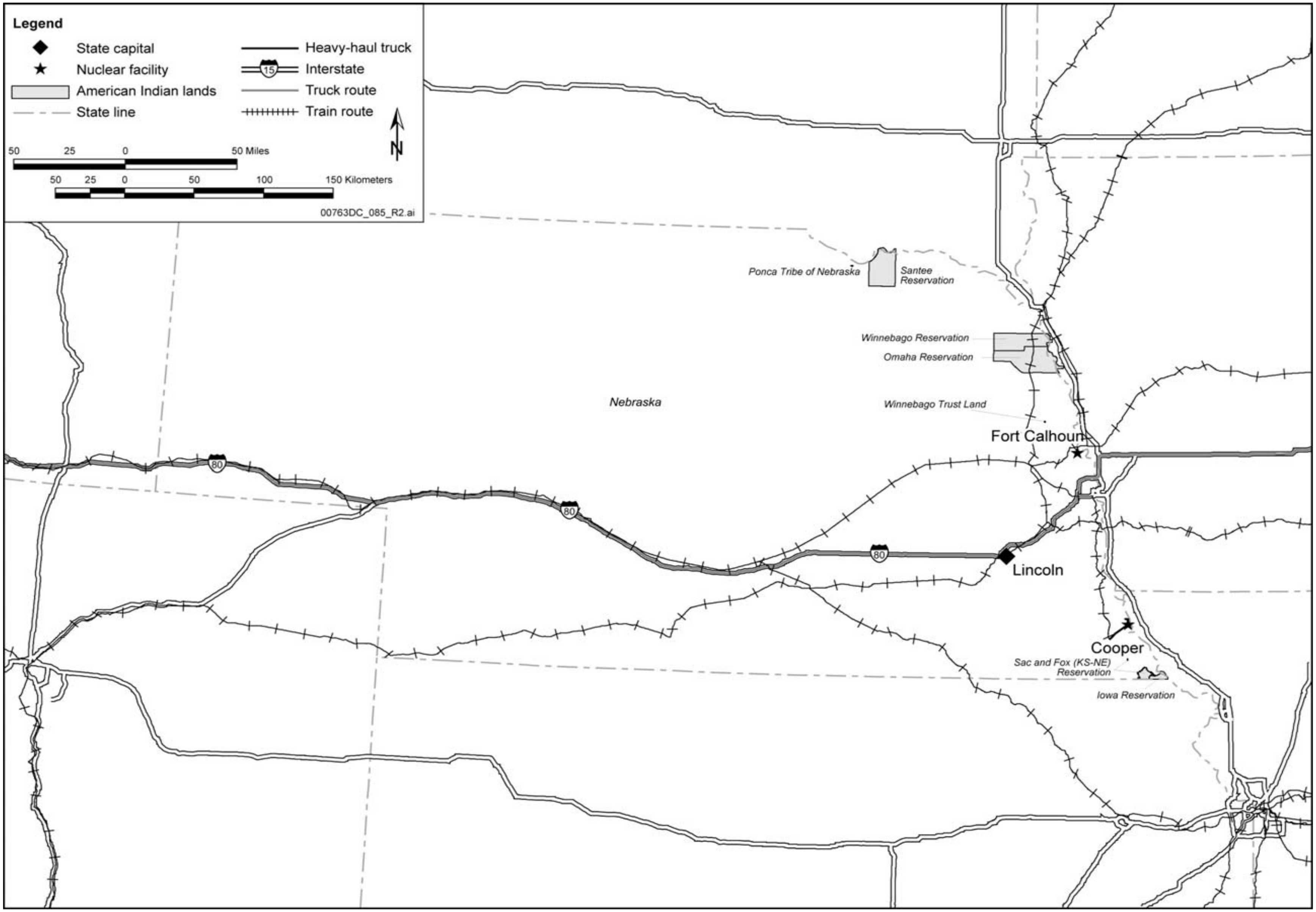

Figure G-26. Representative transportation routes for the State of Nebraska.

Table G-46. Estimated transportation impacts for the State of Nevada.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	9,495	16	680	0.0096	0.41	0.020	0.075	4.5×10^{-5}	0.34	0.78
Truck	2,650	21	95	0.012	0.057	0.0046	0.0032	1.9×10^{-6}	0.050	0.12
Total	12,145	37	770	0.022	0.46	0.024	0.078	4.7×10^{-5}	0.39	0.90
Mina										
Rail	9,495	30	1,500	0.018	0.88	0.037	0.10	6.3×10^{-5}	0.58	1.5
Truck	2,650	21	95	0.012	0.057	0.0046	0.0032	1.9×10^{-6}	0.050	0.12
Total	12,145	50	1,600	0.030	0.94	0.042	0.11	6.5×10^{-5}	0.63	1.6

a. Totals might differ from sums of values due to rounding.

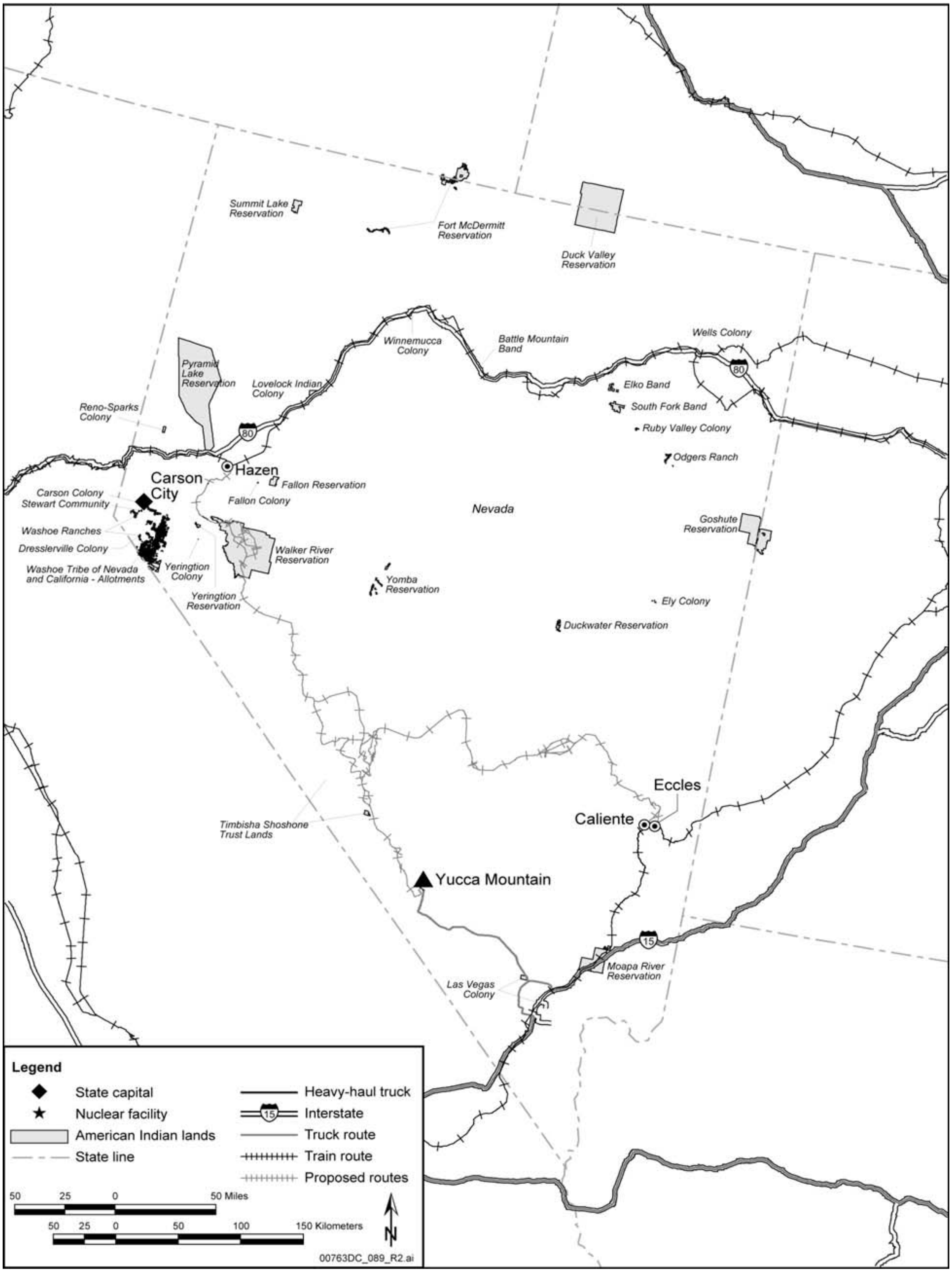

Figure G-27. Representative transportation routes for the State of Nevada.

Table G-47. Estimated transportation impacts for the State of New Hampshire.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	110	0.41	3.4	2.5×10^{-4}	0.0020	5.6×10^{-4}	0.0023	1.4×10^{-6}	4.0×10^{-4}	0.0032
Truck	0	0	0	0	0	0	0	0	0	0
Total	110	0.41	3.4	2.5×10^{-4}	0.0020	5.6×10^{-4}	0.0023	1.4×10^{-6}	4.0×10^{-4}	0.0032
Mina										
Rail	110	0.41	3.4	2.5×10^{-4}	0.0020	5.6×10^{-4}	0.0023	1.4×10^{-6}	4.0×10^{-4}	0.0032
Truck	0	0	0	0	0	0	0	0	0	0
Total	110	0.41	3.4	2.5×10^{-4}	0.0020	5.6×10^{-4}	0.0023	1.4×10^{-6}	4.0×10^{-4}	0.0032

a. Totals might differ from sums of values due to rounding.

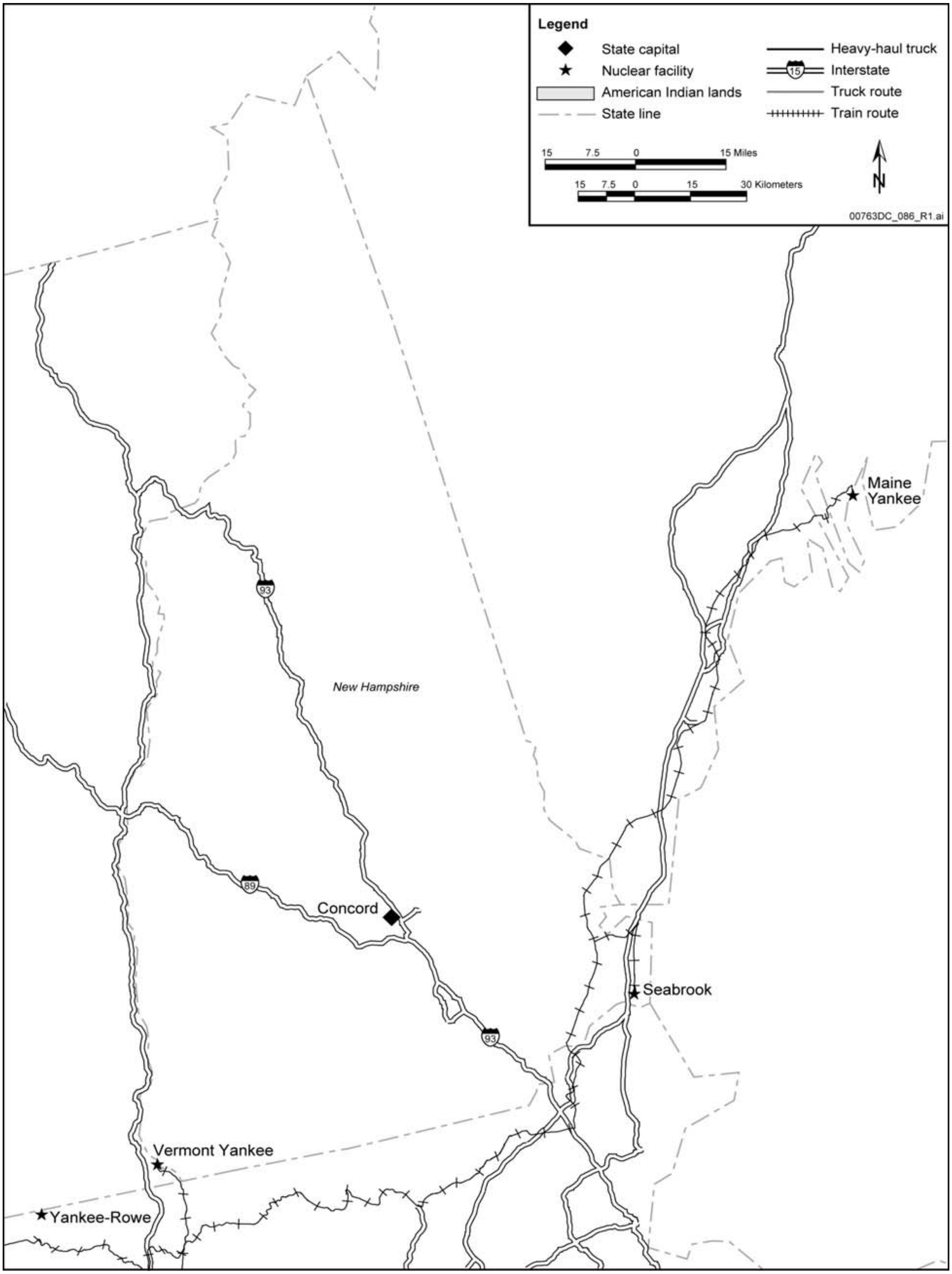

Figure G-28. Representative transportation routes for the State of New Hampshire.

Table G-48. Estimated transportation impacts for the State of New Jersey.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	276	8.2	56	0.0049	0.033	0.0066	0.031	1.9×10^{-5}	0.0031	0.048
Truck	0	0	0	0	0	0	0	0	0	0
Total	276	8.2	56	0.0049	0.033	0.0066	0.031	1.9×10^{-5}	0.0031	0.048
Mina										
Rail	276	8.2	56	0.0049	0.033	0.0066	0.031	1.9×10^{-5}	0.0031	0.048
Truck	0	0	0	0	0	0	0	0	0	0
Total	276	8.2	56	0.0049	0.033	0.0066	0.031	1.9×10^{-5}	0.0031	0.048

a. Totals might differ from sums of values due to rounding.

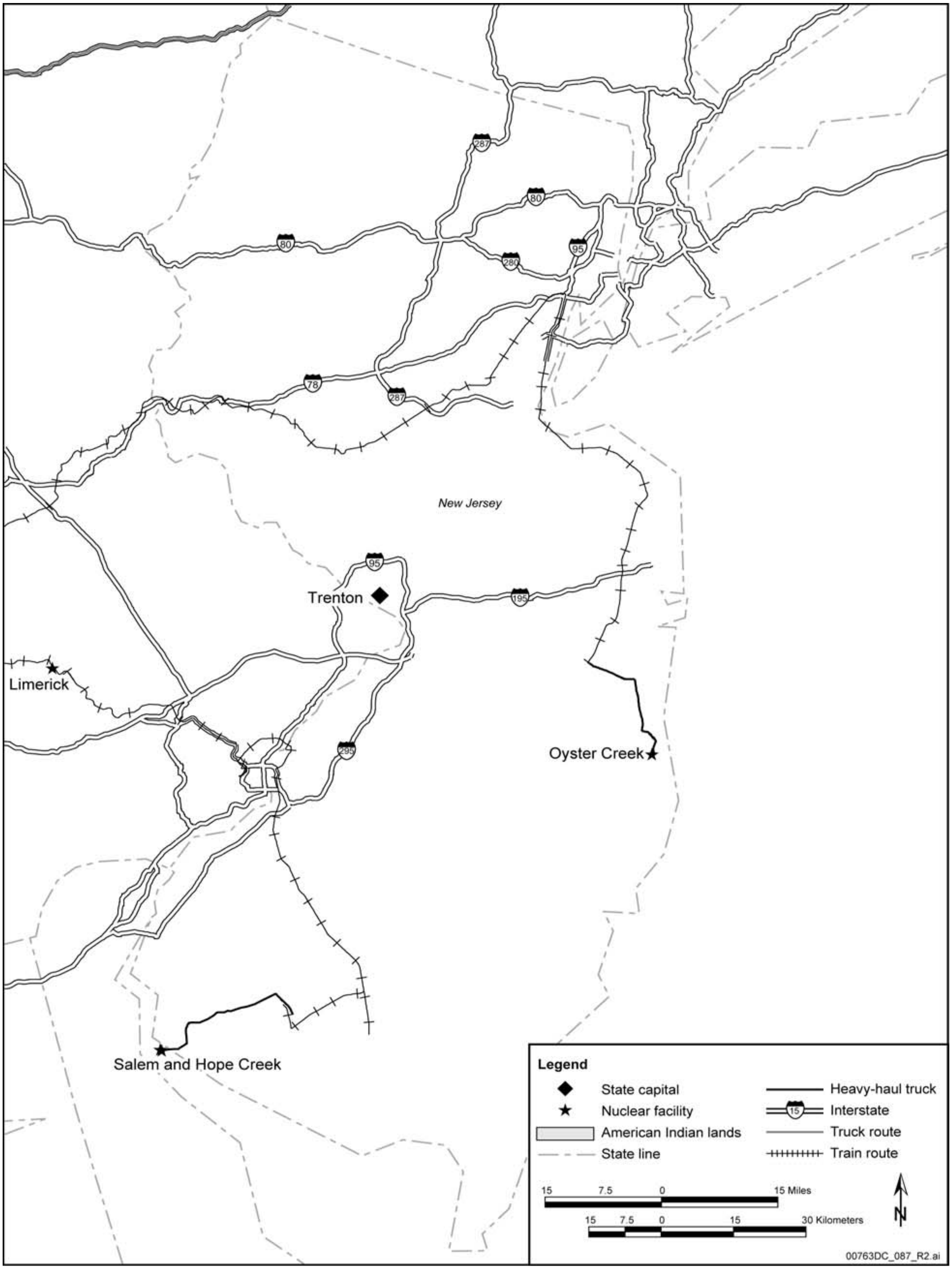

Figure G-29. Representative transportation routes for the State of New Jersey.

Table G-49. Estimated transportation impacts for the State of New Mexico.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	257	0.24	6.0	1.5×10^{-4}	0.0036	3.6×10^{-4}	0.0014	8.6×10^{-7}	0.0043	0.0084
Truck	857	13	34	0.0078	0.020	0.0027	5.7×10^{-4}	3.4×10^{-7}	0.029	0.060
Total	1,114	13	40	0.0080	0.024	0.0031	0.0020	1.2×10^{-6}	0.033	0.069
Mina										
Rail	257	0.17	4.8	9.9×10^{-5}	0.0029	2.5×10^{-4}	9.8×10^{-4}	5.9×10^{-7}	0.0034	0.0067
Truck	857	13	34	0.0078	0.020	0.0027	5.7×10^{-4}	3.4×10^{-7}	0.029	0.060
Total	1,114	13	39	0.0079	0.023	0.0030	0.0015	9.3×10^{-7}	0.033	0.067

a. Totals might differ from sums of values due to rounding.

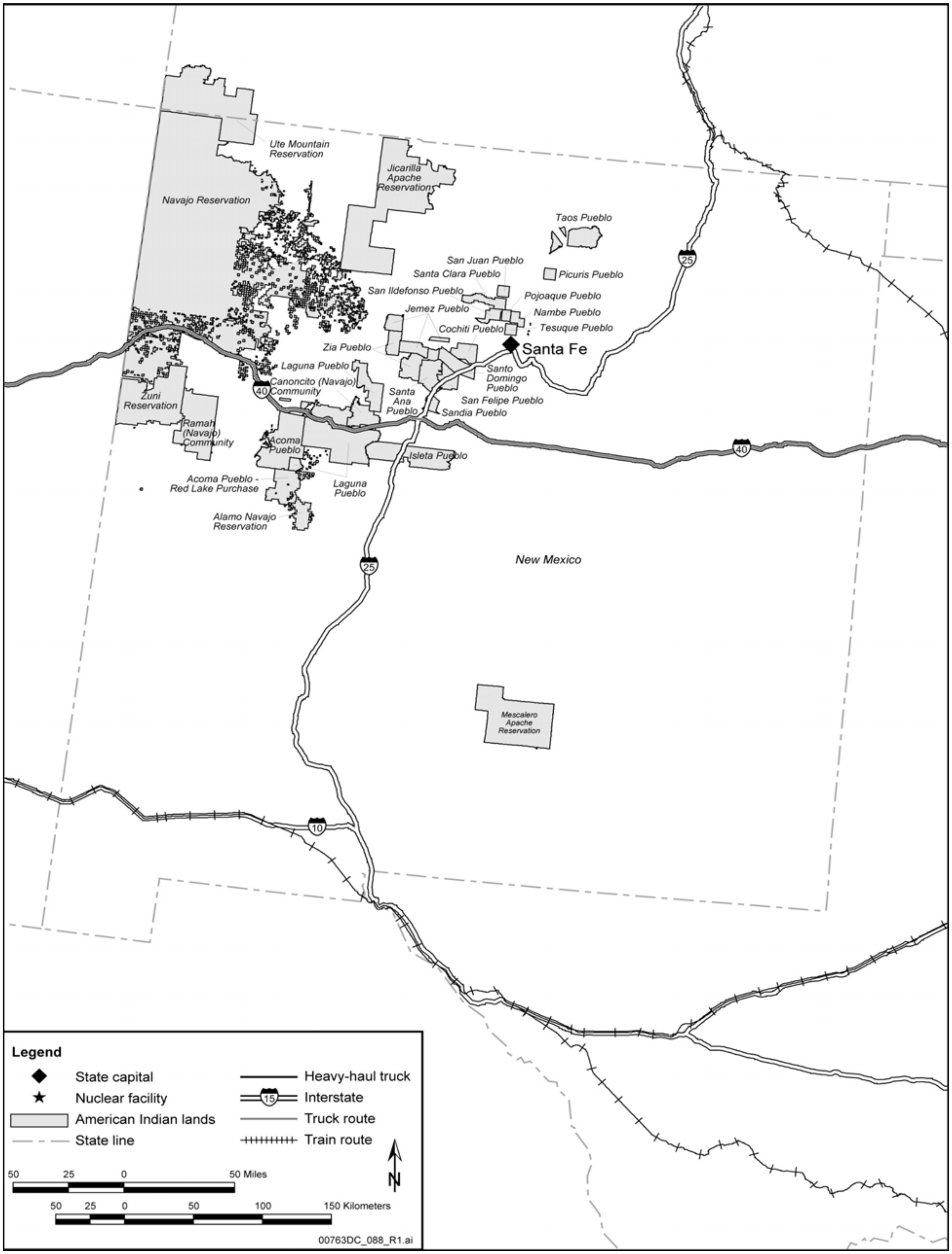

Figure G-30. Representative transportation routes for the State of New Mexico.

Table G-50. Estimated transportation impacts for the State of New York.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	827	14	85	0.0084	0.051	0.018	0.083	5.0×10^{-5}	0.029	0.11
Truck	657	5.4	23	0.0032	0.014	0.0020	0.0013	7.7×10^{-7}	0.0072	0.026
Total	1,484	19	110	0.012	0.065	0.020	0.085	5.1×10^{-5}	0.036	0.13
Mina										
Rail	827	14	85	0.0084	0.051	0.018	0.083	5.0×10^{-5}	0.029	0.11
Truck	657	5.4	23	0.0032	0.014	0.0020	0.0013	7.7×10^{-7}	0.0072	0.026
Total	1,484	19	110	0.012	0.065	0.020	0.085	5.1×10^{-5}	0.036	0.13

a. Totals might differ from sums of values due to rounding.

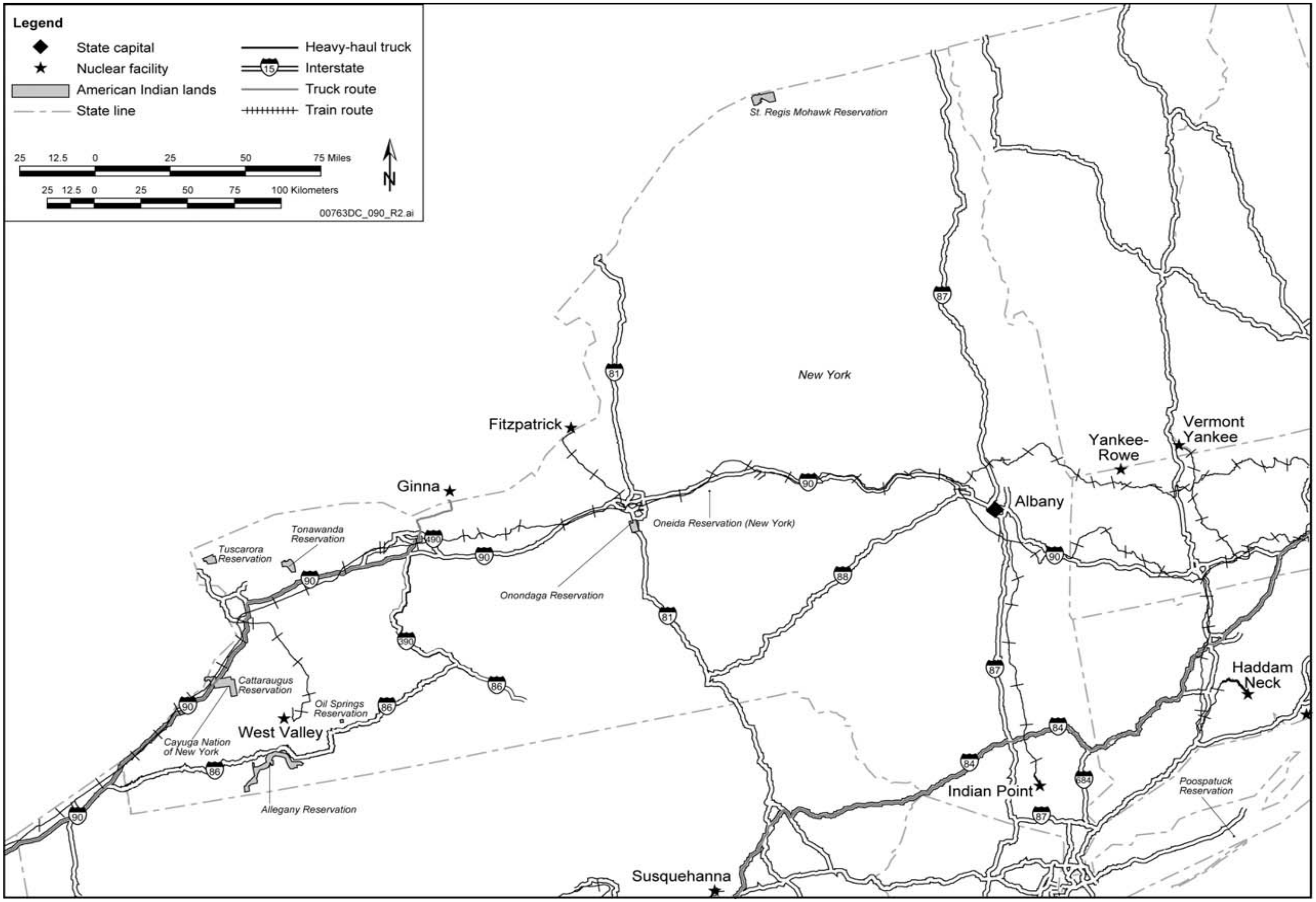

Figure G-31. Representative transportation routes for the State of New York.

Table G-51. Estimated transportation impacts for the State of North Carolina.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	502	7.1	35	0.0042	0.021	0.011	0.045	2.7×10^{-5}	0.0094	0.046
Truck	0	0	0	0	0	0	0	0	0	0
Total	502	7.1	35	0.0042	0.021	0.011	0.045	2.7×10^{-5}	0.0094	0.046
Mina										
Rail	502	7.1	35	0.0042	0.021	0.011	0.045	2.7×10^{-5}	0.0094	0.046
Truck	0	0	0	0	0	0	0	0	0	0
Total	502	7.1	35	0.0042	0.021	0.011	0.045	2.7×10^{-5}	0.0094	0.046

a. Totals might differ from sums of values due to rounding.

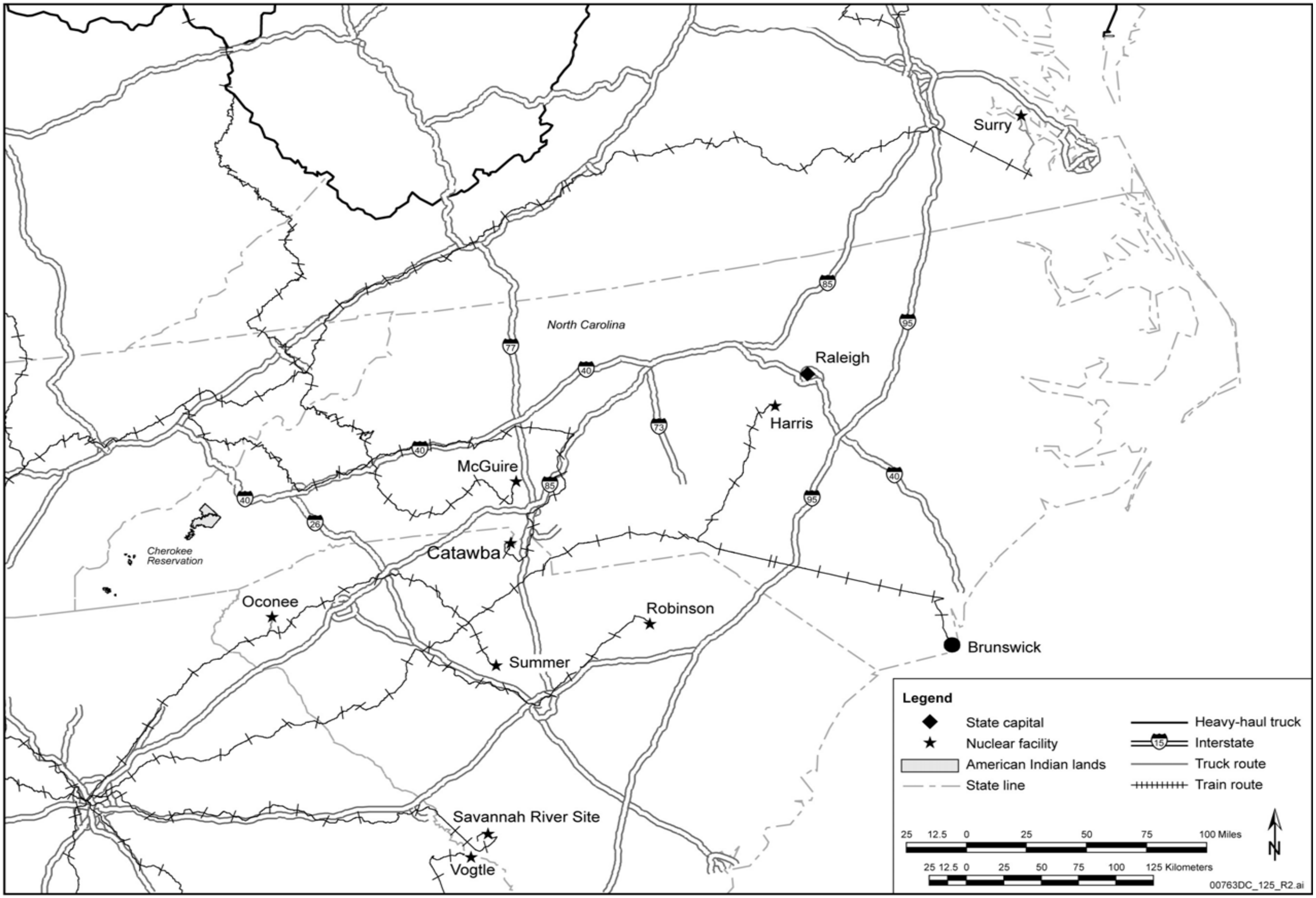

Figure G-32. Representative transportation routes for the State of North Carolina.

Table G-52. Estimated transportation impacts for the State of Ohio.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	2,314	37	100	0.022	0.062	0.049	0.25	1.5×10^{-4}	0.058	0.19
Truck	657	9.8	18	0.0059	0.011	0.0031	9.6×10^{-4}	5.8×10^{-7}	0.0085	0.028
Total	2,971	47	120	0.028	0.073	0.052	0.25	1.5×10^{-4}	0.066	0.22
Mina										
Rail	2,314	37	100	0.022	0.062	0.049	0.25	1.5×10^{-4}	0.058	0.19
Truck	657	9.8	18	0.0059	0.011	0.0031	9.6×10^{-4}	5.8×10^{-7}	0.0085	0.028
Total	2,971	47	120	0.028	0.073	0.052	0.25	1.5×10^{-4}	0.066	0.22

a. Totals might differ from sums of values due to rounding.

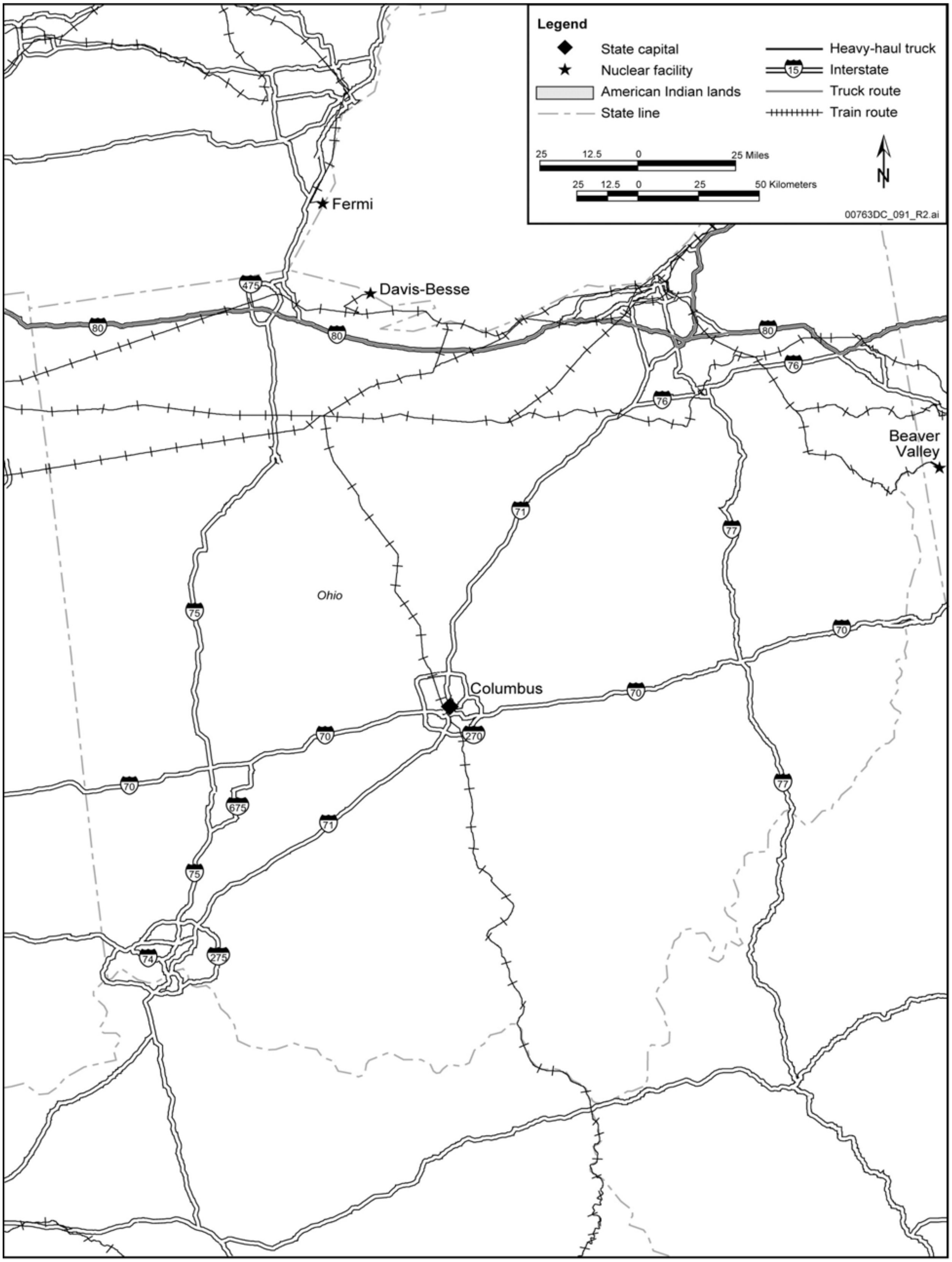

Figure G-33. Representative transportation routes for the State of Ohio.

Table G-53. Estimated transportation impacts for the State of Oklahoma.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	227	0.61	4.9	3.7×10^{-4}	0.0029	0.0010	0.0048	2.9×10^{-6}	0.0033	0.0076
Truck	857	12	26	0.0069	0.015	0.0035	0.0018	1.1×10^{-6}	0.024	0.050
Total	1,084	12	31	0.0073	0.018	0.0045	0.0066	3.9×10^{-6}	0.027	0.057
Mina										
Rail	227	0.61	4.9	3.7×10^{-4}	0.0029	0.0010	0.0048	2.9×10^{-6}	0.0033	0.0076
Truck	857	12	26	0.0069	0.015	0.0035	0.0018	1.1×10^{-6}	0.024	0.050
Total	1,084	12	31	0.0073	0.018	0.0045	0.0066	3.9×10^{-6}	0.027	0.057

a. Totals might differ from sums of values due to rounding.

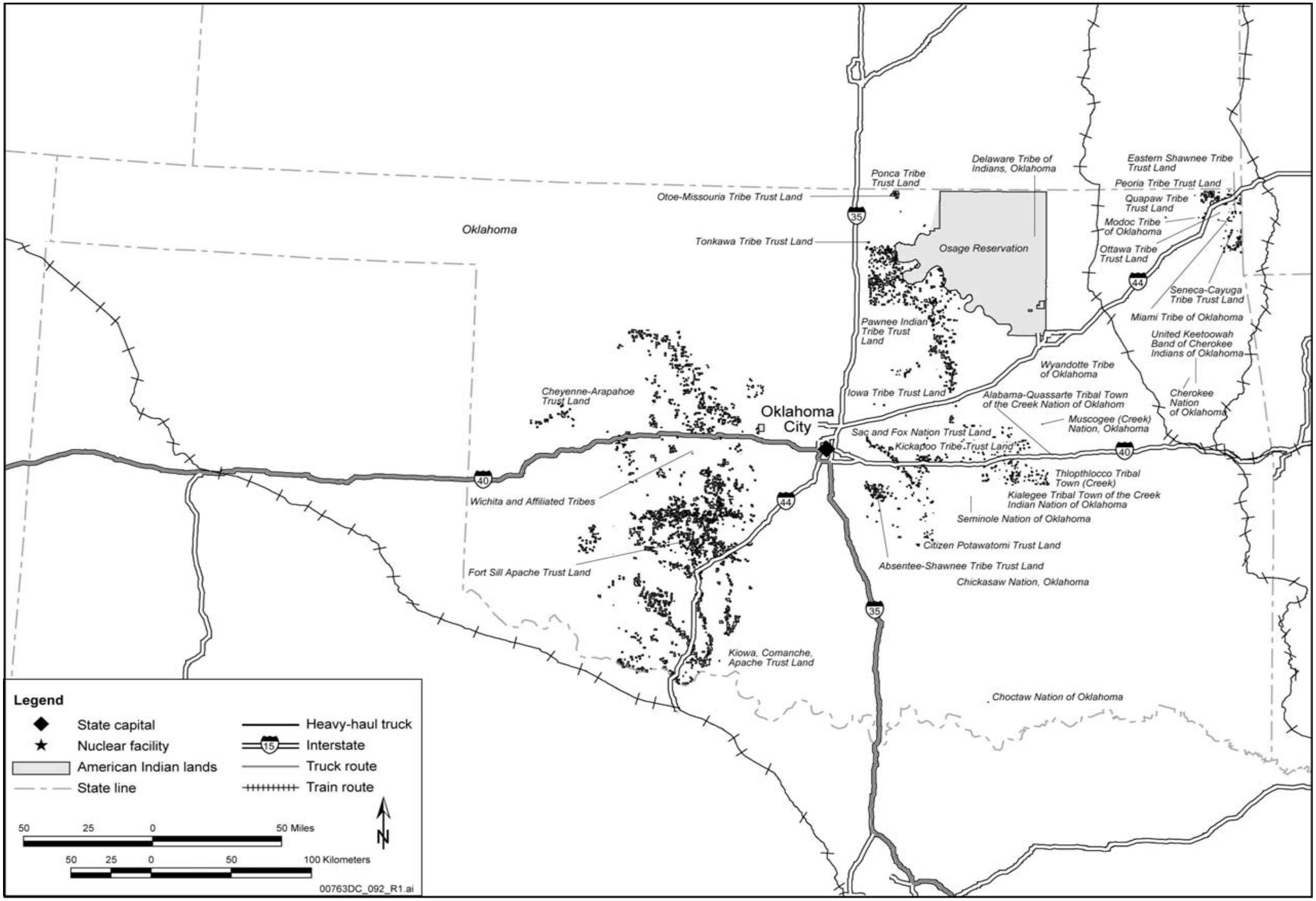

Figure G-34. Representative transportation routes for the State of Oklahoma.

Table G-54. Estimated transportation impacts for the State of Oregon.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	1,307	7.7	33	0.0046	0.020	0.0091	0.012	7.3×10^{-6}	0.025	0.058
Truck	3	0.024	0.067	1.5×10^{-5}	4.0×10^{-5}	5.7×10^{-6}	2.3×10^{-6}	1.4×10^{-9}	8.5×10^{-5}	1.5×10^{-4}
Total	1,310	7.7	33	0.0046	0.020	0.0091	0.012	7.3×10^{-6}	0.025	0.058
Mina										
Rail	1,307	9.4	53	0.0056	0.032	0.012	0.016	9.3×10^{-6}	0.042	0.091
Truck	3	0.024	0.067	1.5×10^{-5}	4.0×10^{-5}	5.7×10^{-6}	2.3×10^{-6}	1.4×10^{-9}	8.5×10^{-5}	1.5×10^{-4}
Total	1,310	9.4	53	0.0056	0.032	0.012	0.016	9.3×10^{-6}	0.042	0.091

a. Totals might differ from sums of values due to rounding.

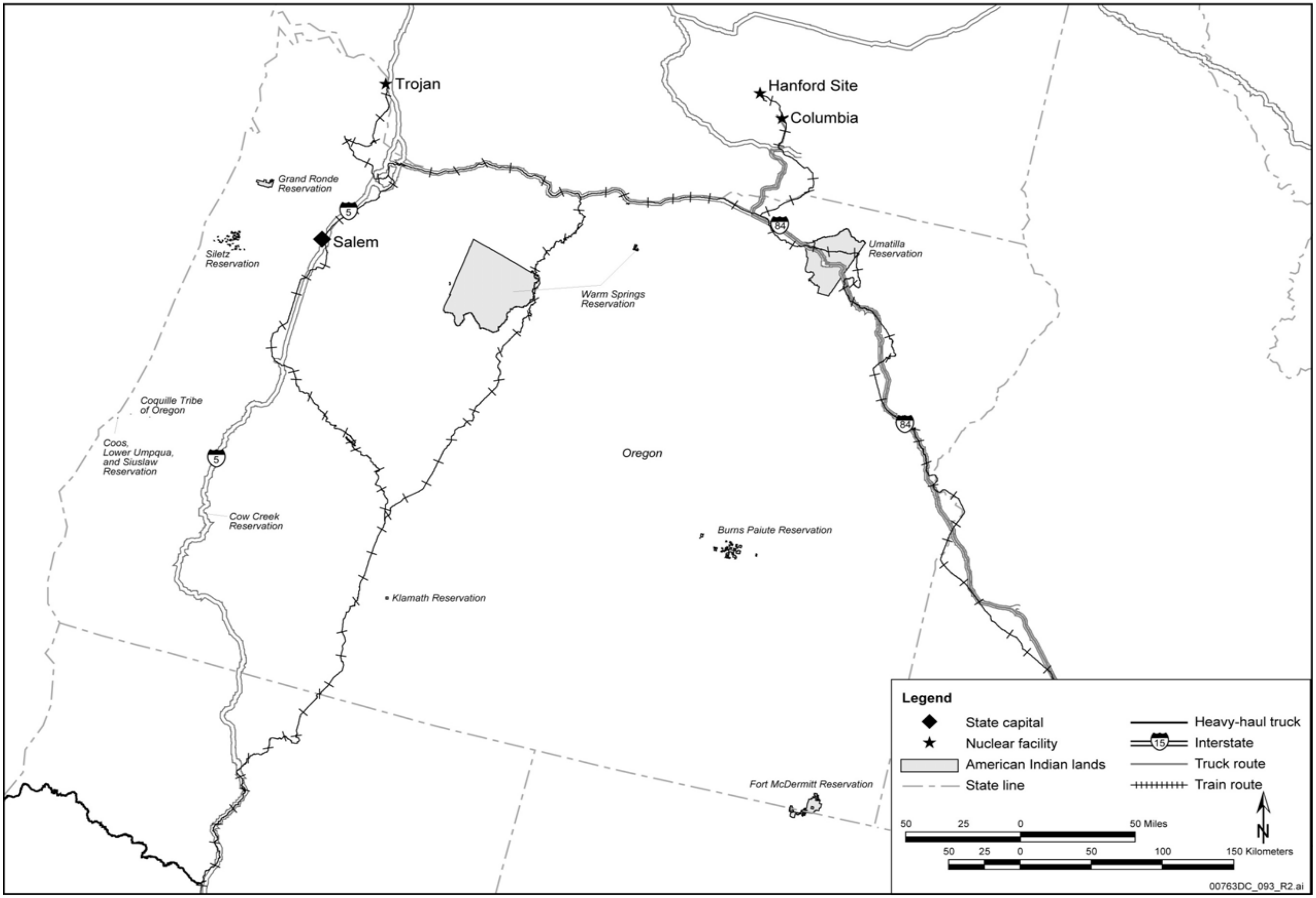

Figure G-35. Representative transportation routes for the State of Oregon.

Table G-55. Estimated transportation impacts for the Commonwealth of Pennsylvania.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	2,036	39	130	0.023	0.080	0.047	0.24	1.4×10^{-4}	0.042	0.19
Truck	657	6.1	15	0.0037	0.0087	0.0012	0.0012	7.1×10^{-7}	0.013	0.027
Total	2,693	45	150	0.027	0.089	0.048	0.24	1.4×10^{-4}	0.056	0.22
Mina										
Rail	2,036	39	130	0.023	0.080	0.047	0.24	1.4×10^{-4}	0.042	0.19
Truck	657	6.1	15	0.0037	0.0087	0.0012	0.0012	7.1×10^{-7}	0.013	0.027
Total	2,693	45	150	0.027	0.089	0.048	0.24	1.4×10^{-4}	0.056	0.22

a. Totals might differ from sums of values due to rounding.

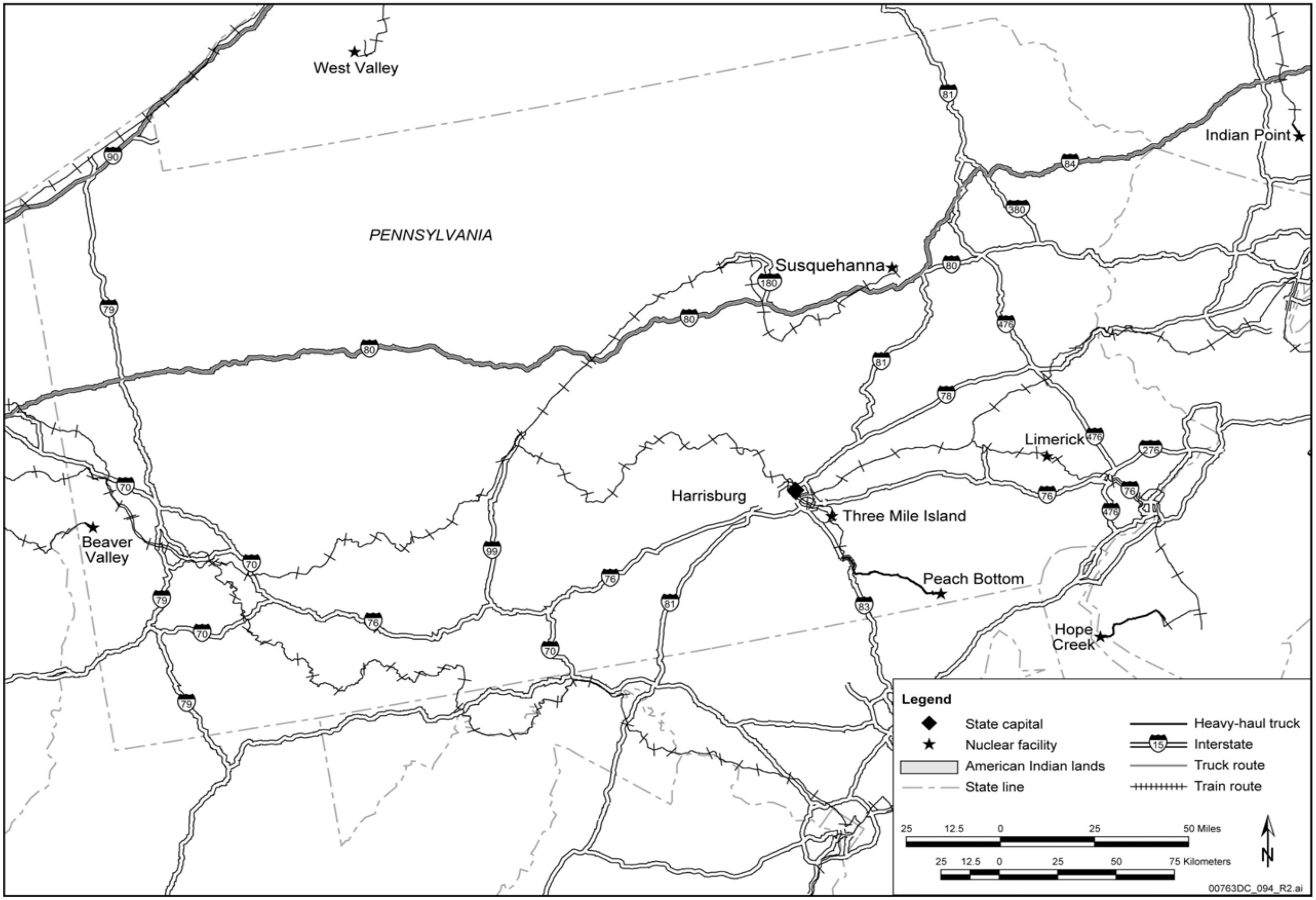

Figure G-36. Representative transportation routes for the Commonwealth of Pennsylvania.

Table G-56. Estimated transportation impacts for the State of South Carolina.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	1,365	4.6	93	0.0027	0.056	0.0035	0.015	8.8×10^{-6}	0.0083	0.070
Truck	0	0	0	0	0	0	0	0	0	0
Total	1,365	4.6	93	0.0027	0.056	0.0035	0.015	8.8×10^{-6}	0.0083	0.070
Mina										
Rail	1,365	4.6	93	0.0027	0.056	0.0035	0.015	8.8×10^{-6}	0.0083	0.070
Truck	0	0	0	0	0	0	0	0	0	0
Total	1,365	4.6	93	0.0027	0.056	0.0035	0.015	8.8×10^{-6}	0.0083	0.070

a. Totals might differ from sums of values due to rounding.

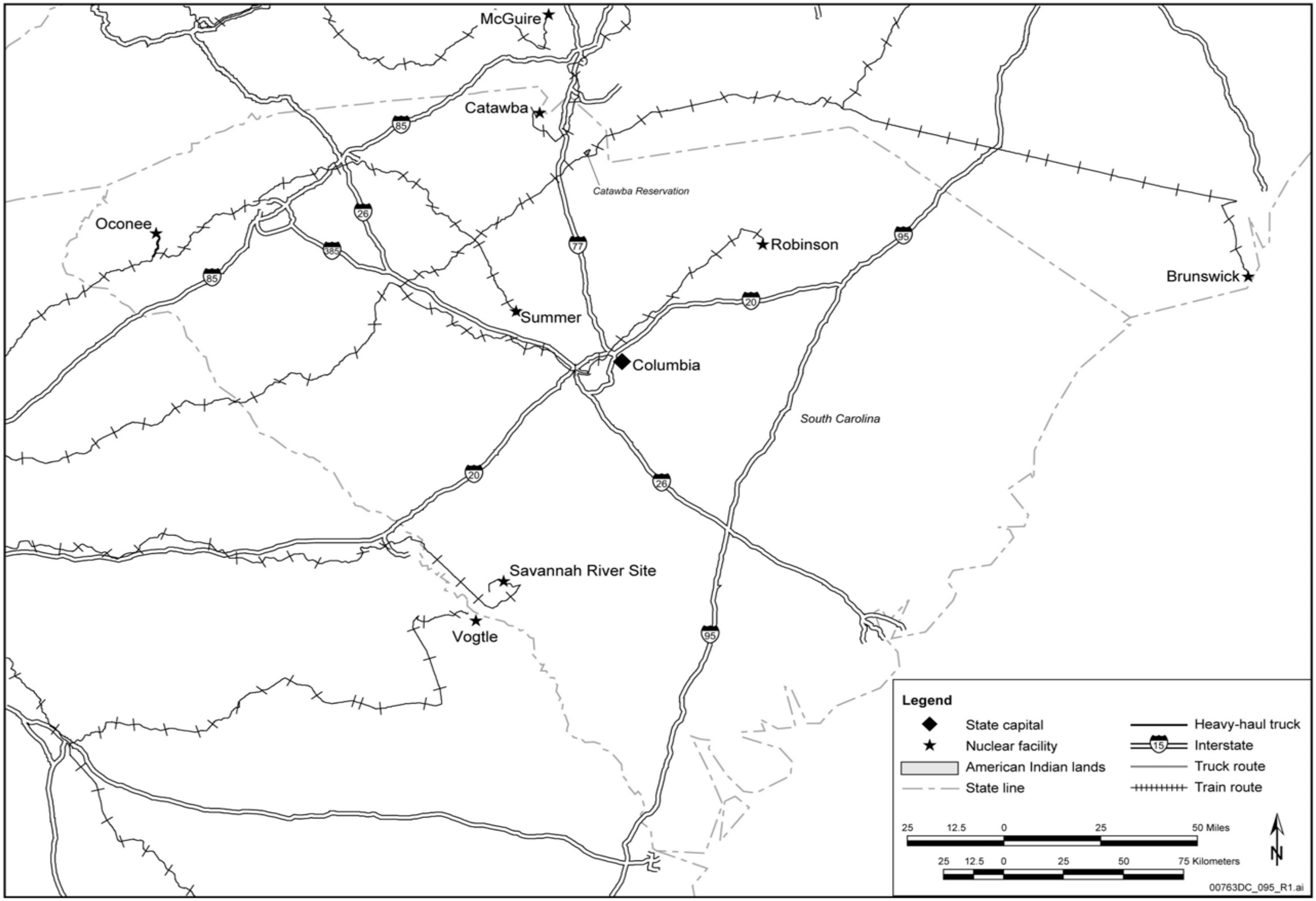

Figure G-37. Representative transportation routes for the State of South Carolina.

Table G-57. Estimated transportation impacts for the State of South Dakota.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	44	0.0045	0.081	2.7×10^{-6}	4.9×10^{-5}	8.1×10^{-6}	5.6×10^{-5}	3.4×10^{-8}	5.6×10^{-5}	1.2×10^{-4}
Truck	0	0	0	0	0	0	0	0	0	0
Total	44	0.0045	0.081	2.7×10^{-6}	4.9×10^{-5}	8.1×10^{-6}	5.6×10^{-5}	3.4×10^{-8}	5.6×10^{-5}	1.2×10^{-4}
Mina										
Rail	44	0.0045	0.081	2.7×10^{-6}	4.9×10^{-5}	8.1×10^{-6}	5.6×10^{-5}	3.4×10^{-8}	5.6×10^{-5}	1.2×10^{-4}
Truck	0	0	0	0	0	0	0	0	0	0
Total	44	0.0045	0.081	2.7×10^{-6}	4.9×10^{-5}	8.1×10^{-6}	5.6×10^{-5}	3.4×10^{-8}	5.6×10^{-5}	1.2×10^{-4}

a. Totals might differ from sums of values due to rounding.

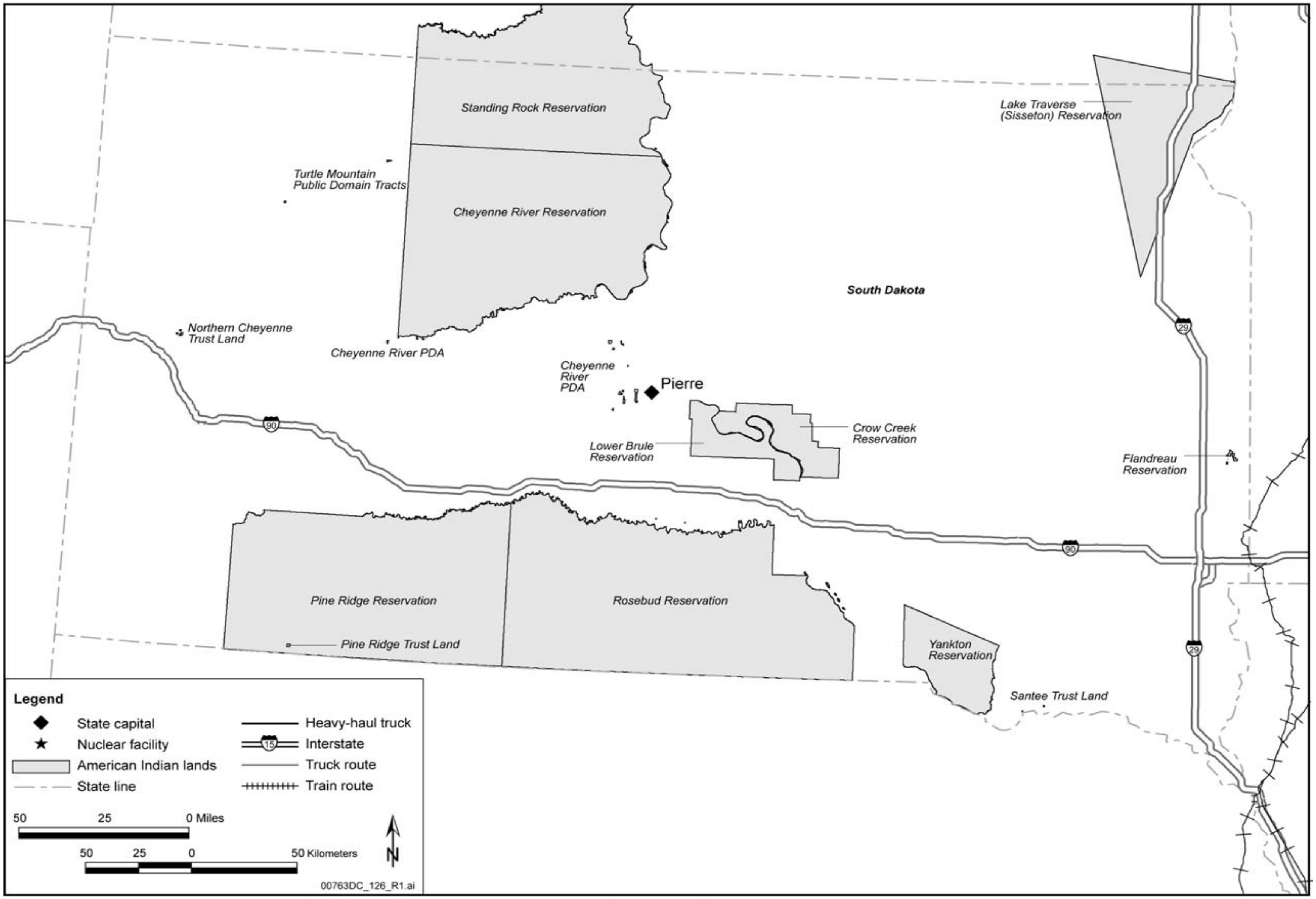

Figure G-38. Representative transportation routes for the State of South Dakota.

Table G-58. Estimated transportation impacts for the State of Tennessee.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	2,663	29	70	0.018	0.042	0.039	0.12	7.1×10^{-5}	0.040	0.14
Truck	0	0	0	0	0	0	0	0	0	0
Total	2,663	29	70	0.018	0.042	0.039	0.12	7.1×10^{-5}	0.040	0.14
Mina										
Rail	2,663	29	70	0.018	0.042	0.039	0.12	7.1×10^{-5}	0.040	0.14
Truck	0	0	0	0	0	0	0	0	0	0
Total	2,663	29	70	0.018	0.042	0.039	0.12	7.1×10^{-5}	0.040	0.14

a. Totals might differ from sums of values due to rounding.

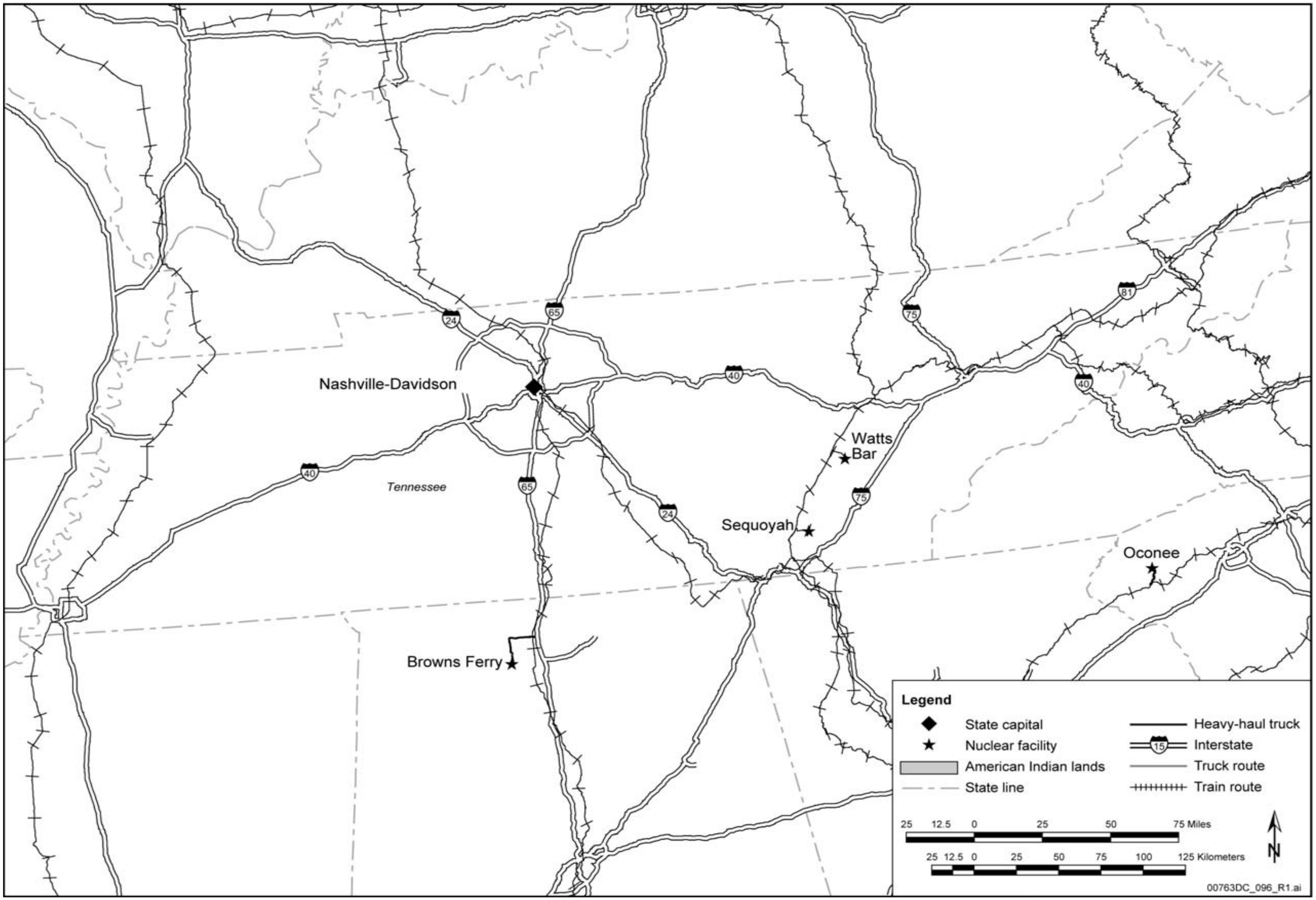

Figure G-39. Representative transportation routes for the State of Tennessee.

Table G-59. Estimated transportation impacts for the State of Texas.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	357	15	41	0.0087	0.025	0.020	0.076	4.6×10^{-5}	0.021	0.074
Truck	857	30	39	0.018	0.023	0.019	0.021	1.2×10^{-5}	0.035	0.096
Total	1,214	44	80	0.027	0.048	0.039	0.097	5.8×10^{-5}	0.056	0.17
Mina										
Rail	357	12	39	0.0073	0.023	0.017	0.064	3.8×10^{-5}	0.019	0.066
Truck	857	30	39	0.018	0.023	0.019	0.021	1.2×10^{-5}	0.035	0.096
Total	1,214	42	78	0.025	0.047	0.035	0.085	5.1×10^{-5}	0.055	0.16

a. Totals might differ from sums of values due to rounding.

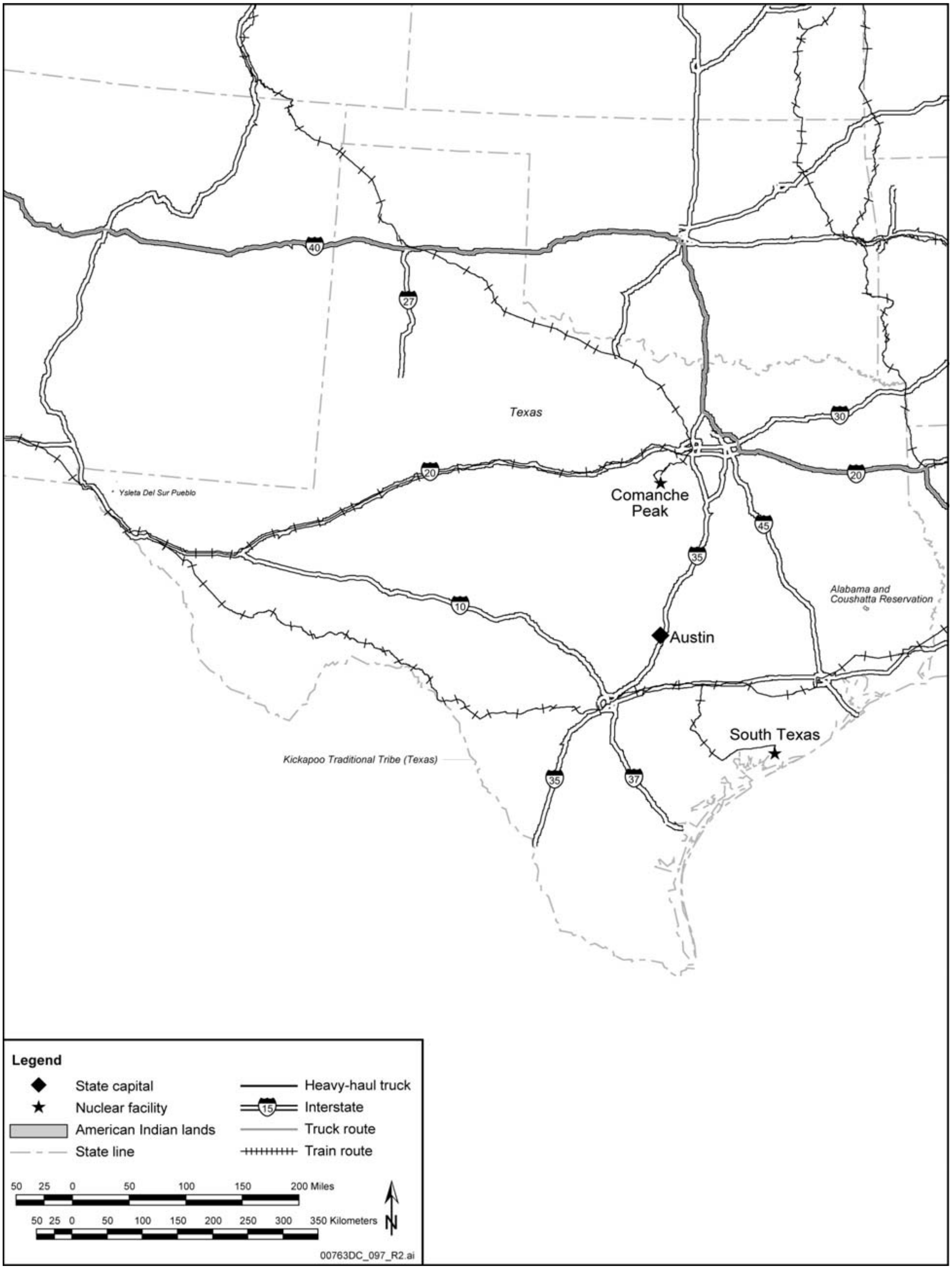

Figure G-40. Representative transportation routes for the State of Texas.

Table G-60. Estimated transportation impacts for the State of Utah.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	8,740	190	950	0.12	0.57	0.23	0.80	4.8×10^{-4}	0.31	1.2
Truck	1,793	50	73	0.030	0.044	0.030	0.016	9.5×10^{-6}	0.063	0.17
Total	10,533	240	1,000	0.15	0.62	0.26	0.81	4.9×10^{-4}	0.38	1.4
Mina										
Rail	7,532	33	420	0.020	0.25	0.045	0.19	1.1×10^{-4}	0.14	0.45
Truck	1,793	50	73	0.030	0.044	0.030	0.016	9.5×10^{-6}	0.063	0.17
Total	9,325	83	490	0.050	0.30	0.075	0.21	1.2×10^{-4}	0.20	0.62

a. Totals might differ from sums of values due to rounding.

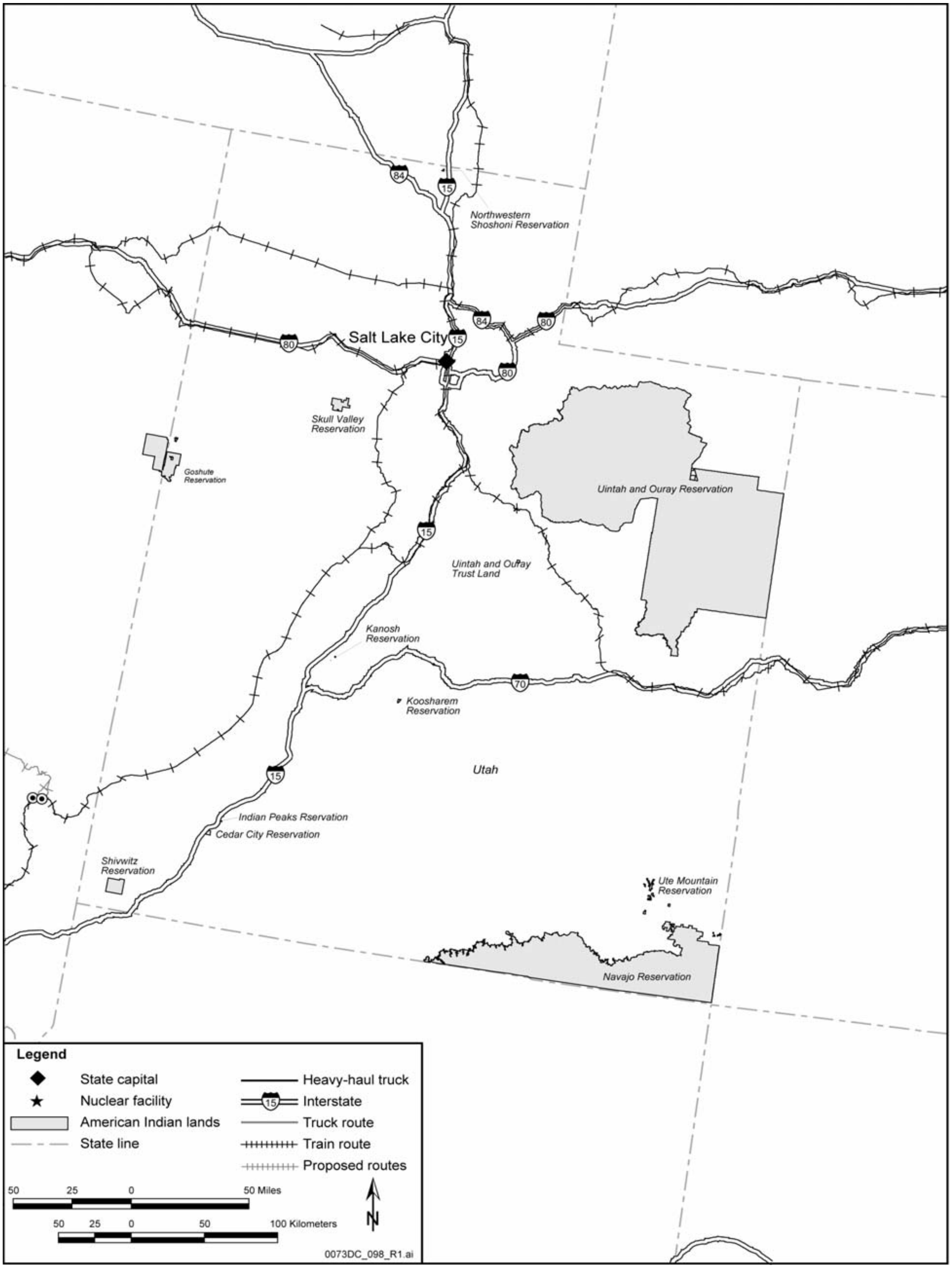

Figure G-41. Representative transportation routes for the State of Utah.

Table G-61. Estimated transportation impacts for the State of Vermont.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	199	0.087	4.2	5.2×10^{-5}	0.0025	3.9×10^{-5}	2.1×10^{-4}	1.3×10^{-7}	1.9×10^{-4}	0.0028
Truck	0	0	0	0	0	0	0	0	0	0
Total	199	0.087	4.2	5.2×10^{-5}	0.0025	3.9×10^{-5}	2.1×10^{-4}	1.3×10^{-7}	1.9×10^{-4}	0.0028
Mina										
Rail	199	0.087	4.2	5.2×10^{-5}	0.0025	3.9×10^{-5}	2.1×10^{-4}	1.3×10^{-7}	1.9×10^{-4}	0.0028
Truck	0	0	0	0	0	0	0	0	0	0
Total	199	0.087	4.2	5.2×10^{-5}	0.0025	3.9×10^{-5}	2.1×10^{-4}	1.3×10^{-7}	1.9×10^{-4}	0.0028

a. Totals might differ from sums of values due to rounding.

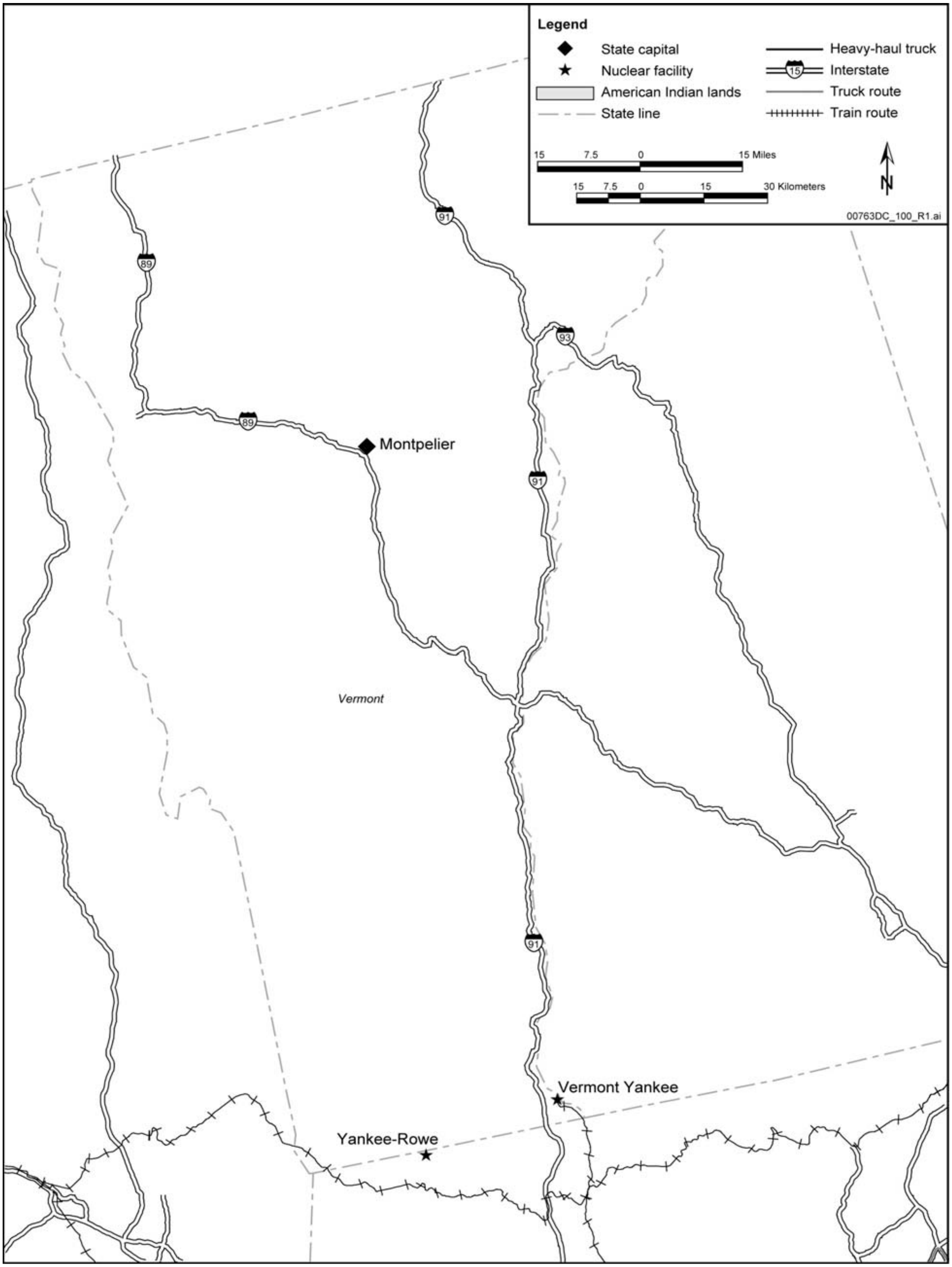

Figure G-42. Representative transportation routes for the State of Vermont.

Table G-62. Estimated transportation impacts for the Commonwealth of Virginia.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	390	5.9	40	0.0036	0.024	0.0060	0.023	1.4×10^{-5}	0.0078	0.041
Truck	0	0	0	0	0	0	0	0	0	0
Total	390	5.9	40	0.0036	0.024	0.0060	0.023	1.4×10^{-5}	0.0078	0.041
Mina										
Rail	390	5.9	40	0.0036	0.024	0.0060	0.023	1.4×10^{-5}	0.0078	0.041
Truck	0	0	0	0	0	0	0	0	0	0
Total	390	5.9	40	0.0036	0.024	0.0060	0.023	1.4×10^{-5}	0.0078	0.041

a. Totals might differ from sums of values due to rounding.

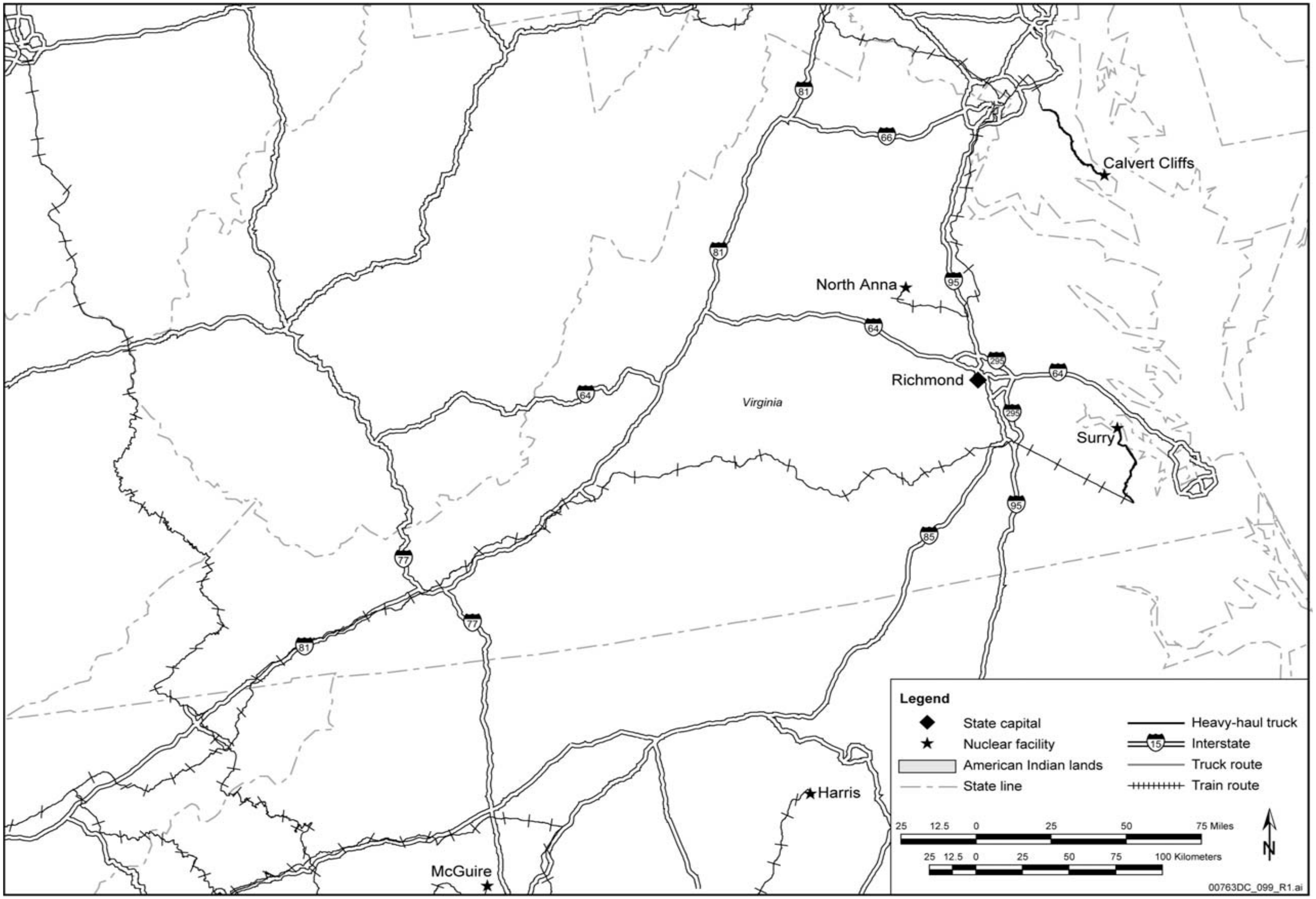

Figure G-43. Representative transportation routes for the Commonwealth of Virginia.

Table G-63. Estimated transportation impacts for the State of Washington.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	1,274	7.9	73	0.0047	0.044	0.0066	0.0045	2.7×10^{-6}	0.0066	0.062
Truck	3	0.0098	0.15	5.9×10^{-6}	9.3×10^{-5}	4.9×10^{-6}	2.4×10^{-6}	1.4×10^{-9}	6.8×10^{-6}	1.1×10^{-4}
Total	1,277	7.9	73	0.0047	0.044	0.0066	0.0045	2.7×10^{-6}	0.0066	0.062
Mina										
Rail	1,274	7.9	73	0.0047	0.044	0.0066	0.0045	2.7×10^{-6}	0.0066	0.062
Truck	3	0.0098	0.15	5.9×10^{-6}	9.3×10^{-5}	4.9×10^{-6}	2.4×10^{-6}	1.4×10^{-9}	6.8×10^{-6}	1.1×10^{-4}
Total	1,277	7.9	73	0.0047	0.044	0.0066	0.0045	2.7×10^{-6}	0.0066	0.062

a. Totals might differ from sums of values due to rounding.

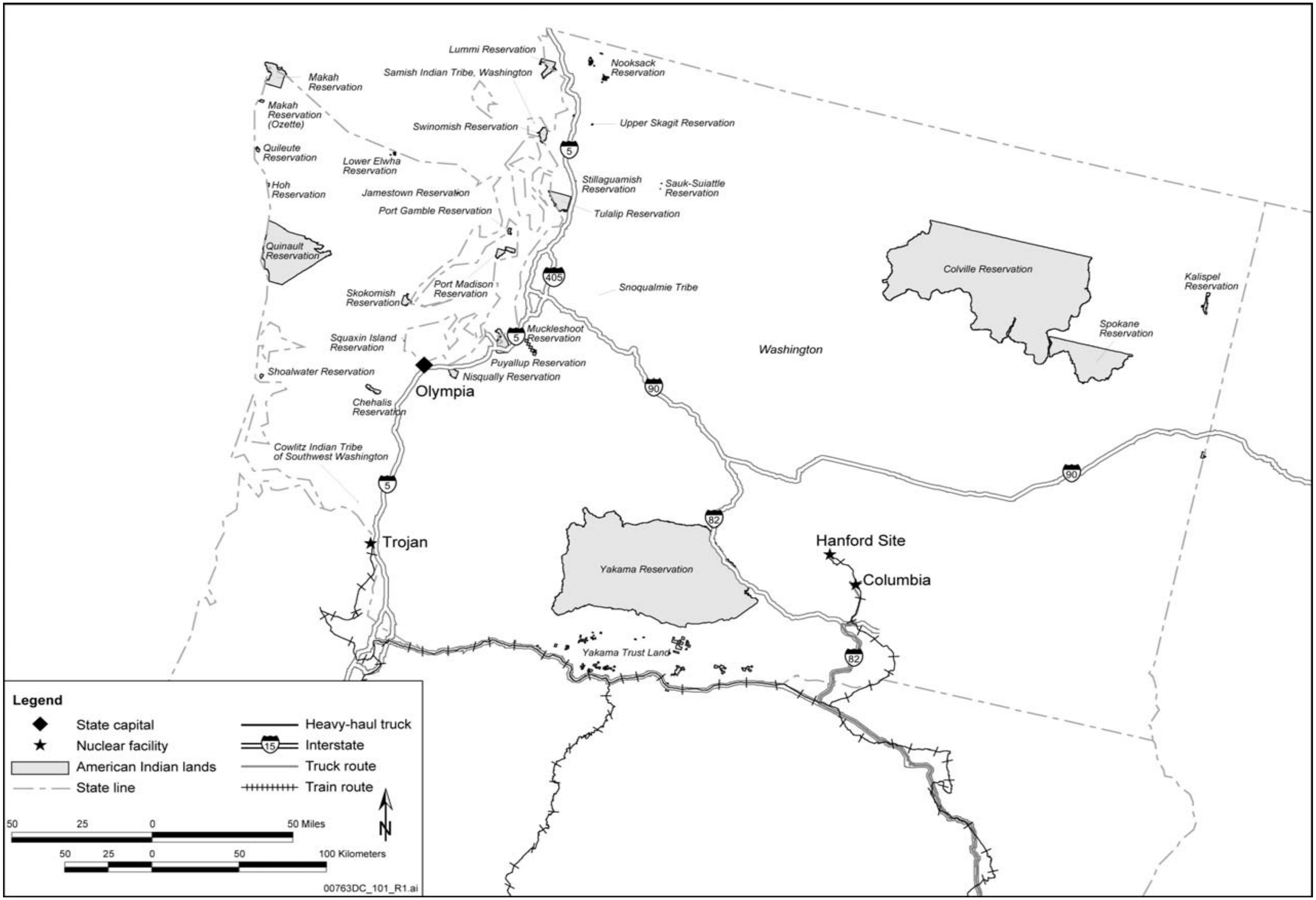

Figure G-44. Representative transportation routes for the State of Washington.

Table G-64. Estimated transportation impacts for the State of West Virginia.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	255	0.30	3.3	1.8×10^{-4}	0.0020	4.6×10^{-4}	0.0018	1.1×10^{-6}	0.0022	0.0048
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	0.30	3.3	1.8×10^{-4}	0.0020	4.6×10^{-4}	0.0018	1.1×10^{-6}	0.0022	0.0048
Mina										
Rail	255	0.30	3.3	1.8×10^{-4}	0.0020	4.6×10^{-4}	0.0018	1.1×10^{-6}	0.0022	0.0048
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	0.30	3.3	1.8×10^{-4}	0.0020	4.6×10^{-4}	0.0018	1.1×10^{-6}	0.0022	0.0048

a. Totals might differ from sums of values due to rounding.

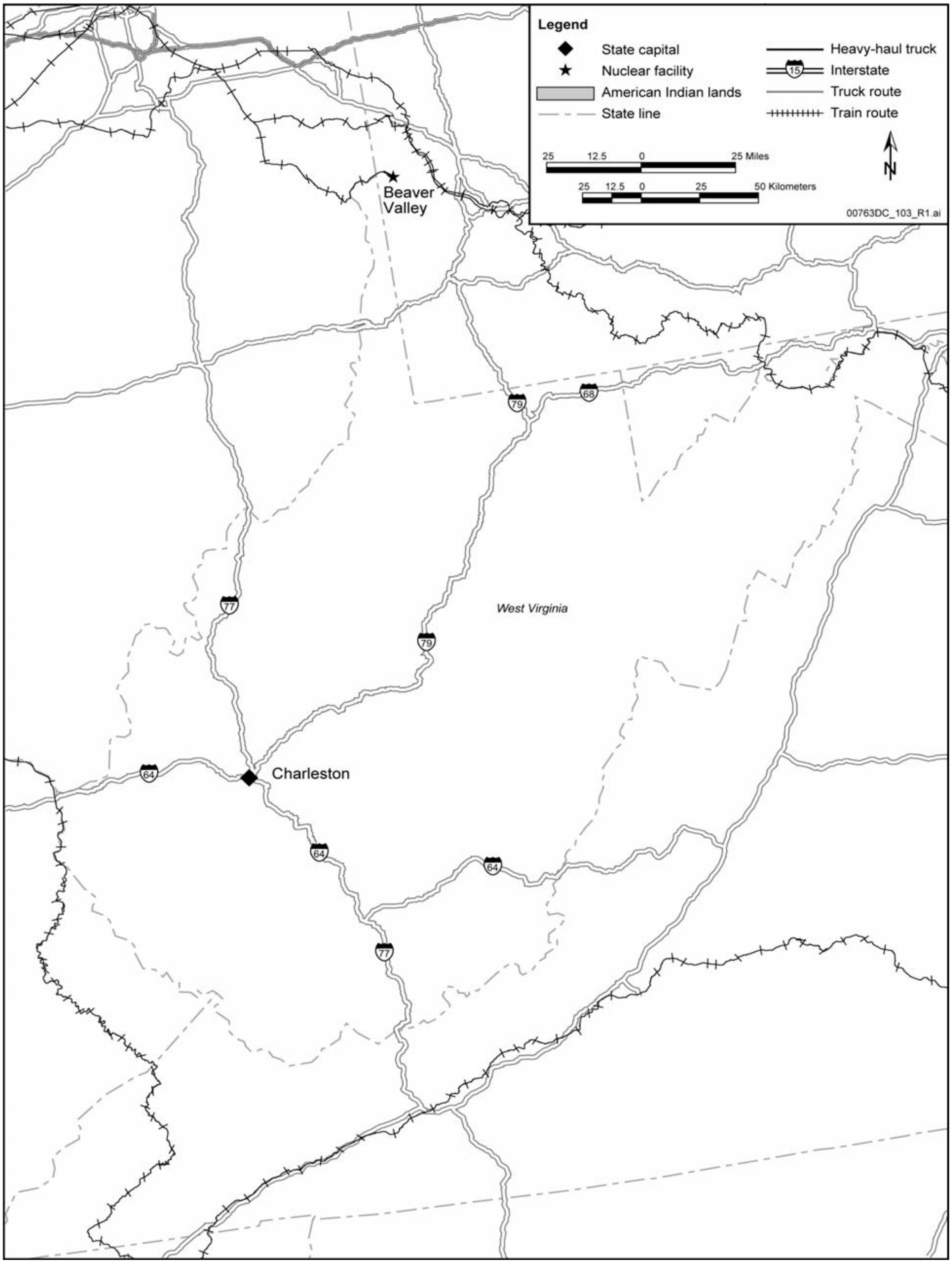

Figure G-45. Representative transportation routes for the State of West Virginia.

Table G-65. Estimated transportation impacts for the State of Wisconsin.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	152	3.5	33	0.0021	0.020	0.0031	0.013	7.6×10^{-6}	0.0038	0.029
Truck	37	0.089	1.8	5.3×10^{-5}	0.0011	4.4×10^{-5}	3.7×10^{-5}	2.2×10^{-8}	7.5×10^{-5}	0.0012
Total	189	3.5	34	0.0021	0.021	0.0031	0.013	7.6×10^{-6}	0.0038	0.030
Mina										
Rail	152	3.5	33	0.0021	0.020	0.0031	0.013	7.6×10^{-6}	0.0038	0.029
Truck	37	0.089	1.8	5.3×10^{-5}	0.0011	4.4×10^{-5}	3.7×10^{-5}	2.2×10^{-8}	7.5×10^{-5}	0.0012
Total	189	3.5	34	0.0021	0.021	0.0031	0.013	7.6×10^{-6}	0.0038	0.030

a. Totals might differ from sums of values due to rounding.

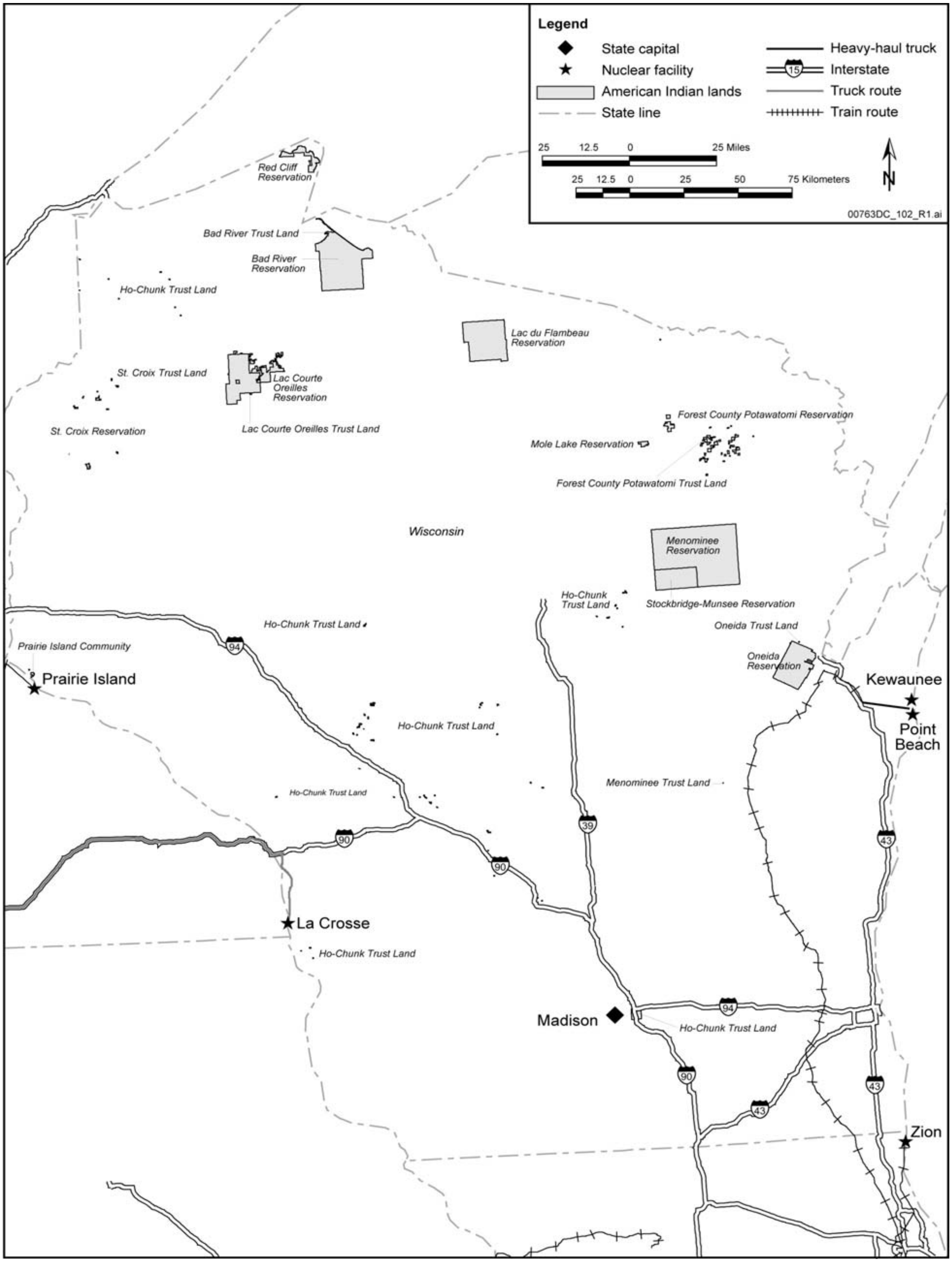

Figure G-46. Representative transportation routes for the State of Wisconsin.

Table G-66. Estimated transportation impacts for the State of Wyoming.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	6,354	18	390	0.011	0.23	0.025	0.11	6.4×10^{-5}	0.28	0.55
Truck	1,789	23	77	0.014	0.046	0.0022	0.0027	1.6×10^{-6}	0.062	0.12
Total	8,143	41	470	0.025	0.28	0.027	0.11	6.5×10^{-5}	0.34	0.67
Mina										
Rail	6,354	18	390	0.011	0.23	0.025	0.11	6.4×10^{-5}	0.28	0.55
Truck	1,789	23	77	0.014	0.046	0.0022	0.0027	1.6×10^{-6}	0.062	0.12
Total	8,143	41	470	0.025	0.28	0.027	0.11	6.5×10^{-5}	0.34	0.67

a. Totals might differ from sums of values due to rounding.

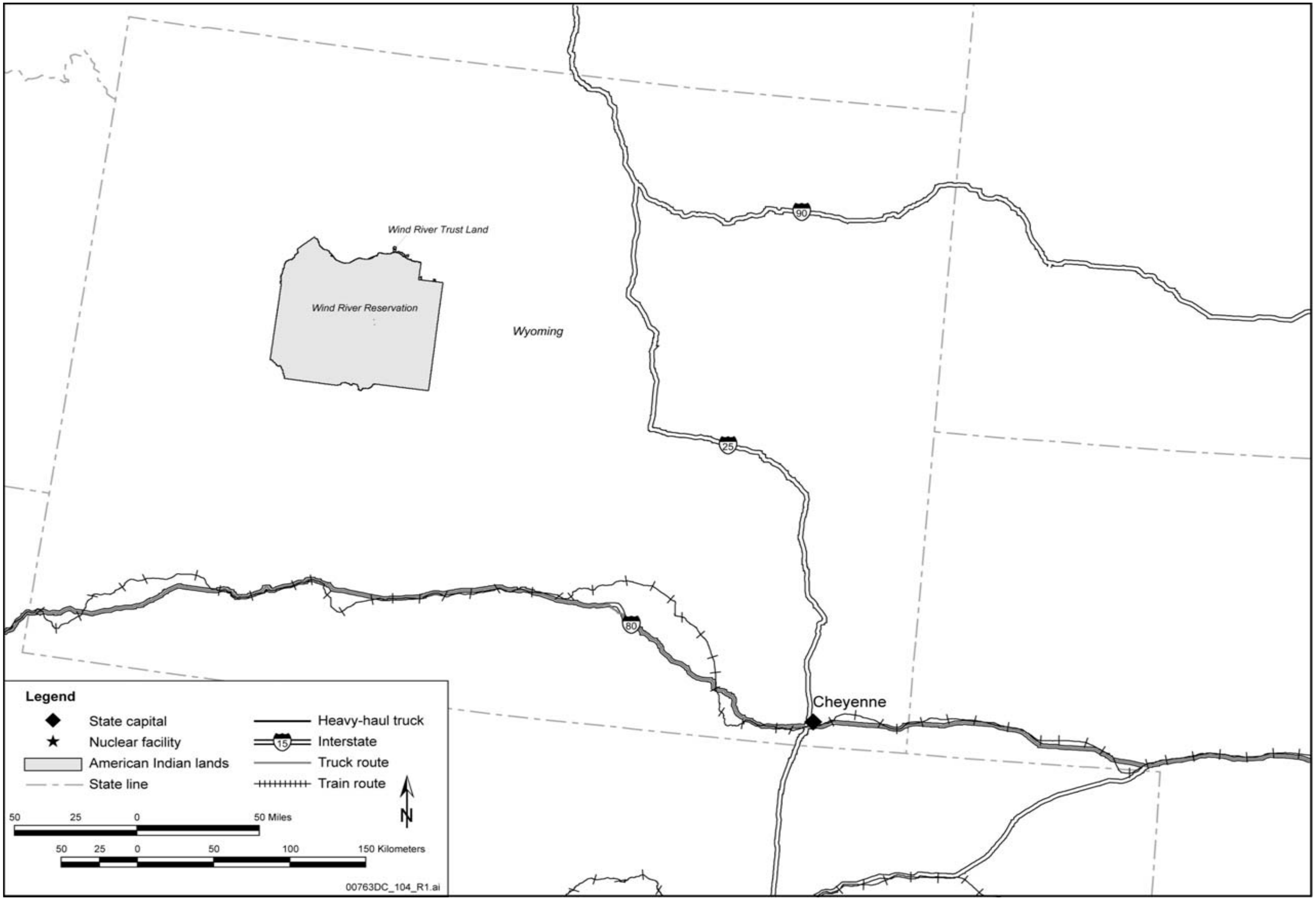

Figure G-47. Representative transportation routes for the State of Wyoming.

G.11 Transport of Other Materials and Personnel

This section summarizes the transportation methods and data used to estimate the impacts from the transportation of personnel and materials other than spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. During repository construction and operation, personnel would travel to the site and to an office in Las Vegas. Materials such as steel and concrete would be required to construct, operate, and close the repository. Fuel oil would be needed throughout the life of the repository, from the start of construction until final closure. During these periods, waste package materials, including TAD canisters that would be used to package the small amount of spent nuclear fuel that would arrive at the repository in truck casks or in dual-purpose canisters contained in rail casks, would have to be transported to the repository. Lastly, small quantities of wastes would be generated and would have to be disposed of off site from the start of construction until final closure.

The approach used to estimate the impacts for the various types of transportation activities that would occur from the start of construction until closure was to estimate the number of trips and representative route for each particular commodity to be shipped. The TRAGIS computer program (DIRS 181276-Johnson and Michelhaugh 2003, all) was used to determine the representative routes and their associated distances and population densities. Population densities were escalated to account for growth to 2067. Other data required for the analysis included vehicle emission unit risk factors and accident fatality rates for various vehicle types, including automobiles, heavy combination trucks, buses, and trains. These and vehicle emission unit risk factors and fatal accident rates are listed in Table G-67.

Table G-67. Vehicle emission unit risk factors and fatal accident rates.

Vehicle type	Vehicle emission unit risk factor (fatality/km per person/km^2)[a]	Accident fatality rate (fatality per km)[b]
Automobile	9.4×10^{-12}	1.2×10^{-8}
Truck	1.5×10^{-11}	1.7×10^{-8}
Bus	1.5×10^{-11}	3.0×10^{-8}
Railcars	2.6×10^{-11}	1.1×10^{-8}

a. To convert fatality/km per person/km^2 to fatality/mile per person/square mile, multiply by 0.62137.
b. To convert fatality per km to fatality per mile, multiply by 1.60934.
km = kilometer.

G.11.1 COMMUTERS

Commuters would travel to and from the repository and to and from an office located in Las Vegas. The transportation impacts for these commuters were based on the methods and data in *Transportation Health and Safety Calculation/Analysis Documentation in Support of the Final EIS for Yucca Mountain Repository* (DIRS 157144-Jason Technologies 2001, Section 6.0) with the following additional assumptions:

- Eighty percent of the site employees would reside in Clark County and the remaining 20 percent in Nye County. Pahrump, the largest town in Nye County, is closer to the repository than Las Vegas. If the workers lived in Pahrump, the impacts would be less because the commuting distance traveled by the workers would be less.

- The bus provided for travel to the repository site would be scheduled to accommodate 90 percent of the employees. Each bus would hold a total of 40 passengers; however, only two-thirds of the workers would choose to take the bus.
- One-third of the site workers would travel to the site in automobiles and on average the automobiles would have 1.3 occupants.
- The average commute from Clark County to the repository would be from downtown Las Vegas, specifically the junction of Interstate Highway 15 and U.S. Highway 95, and the average commute from Nye County to the repository would be from Pahrump.

Table G-68 shows the total number of bus and automobile trips that would be required for up to 50 years for repository construction, operations, monitoring, and closure. The commuter impacts related to the construction and operation of the Caliente or Mina rail alignment are included in the impacts discussed in Chapter 6, Section 6.4.1.11 of this Repository SEIS.

Table G-68. Total bus and automobile trips for commuters.

County	Buses to repository	Automobiles to repository	Automobiles to Las Vegas office
Clark	307,726	3,436,190	3,732,872
Nye	79,316	860,428	0
Total	387,042	4,296,618	3,732,872

G.11.2 WASTE PACKAGE COMPONENTS

The waste package components shipped to the repository would include the disposal containers, emplacement pallets, drip shields, and TAD canisters for spent nuclear fuel coming directly to the repository via truck or in rail casks containing uncanistered spent nuclear fuel or spent nuclear fuel within dual-purpose canisters. Table G-69 lists the number of components that would be shipped.

Table G-69. Waste package components shipped to the repository.

Component	Number
Waste packages	11,177
TAD canisters shipped directly to repository	866
Emplacement pallets (by type)	
Short	1,147
Long	10,030
Total emplacement pallets	11,177
Drip shields	11,500
Dry storage cask shells (aging overpacks)	2,500

G.11.3 CONSTRUCTION AND OPERATIONS MATERIALS

The construction and operations materials would include gasoline and fuel oil as well as concrete, steel and equipment needed to construct, operate, monitor, and close the repository. Shipments of construction materials would include 190,000 metric tons (210,000 tons) of cement; 280,000 metric tons (310,000 tons) of steel; and 670 metric tons (740 tons) of copper. Most of the consumables would be fuel oil; about 8,100 railroad tank cars of fuel oil would be shipped to the repository during the operations period. These materials would be available in either Las Vegas if the Caliente rail alignment was used, or in Reno if the Mina rail alignment was used. The impacts of shipping materials related to the construction and operation of the Caliente or Mina rail alignments are included in the impacts discussion in Chapter 6, Section 6.4.1.11 of this Repository SEIS.

G.11.4 WASTE MATERIALS

DOE would ship waste materials from repository activities off the site for disposal. This waste would include construction and demolition debris, sanitary and industrial waste, hazardous waste, and low-level radioactive wastes. DOE would use one or more of the following to manage construction and demolition debris: disposal at existing landfills at the Nevada Test Site, nearby municipal landfills, or a State-permitted landfill on the Yucca Mountain Site. In addition to the landfills at the Nevada Test Site, there are 20 operating municipal solid waste landfills, which include four industrial landfills, in Nevada. DOE would manage sanitary and industrial waste in the same manner as construction and demolition debris.

For the purposes of analysis in the Repository SEIS, hazardous waste would be disposed of at the EnergySolutions disposal facility in Clive, Utah, and low-level radioactive waste would be disposed of at the commercial low-level radioactive waste disposal facility in Richland, Washington. Table G-70 lists the volumes of materials that would be shipped. The impacts of shipping waste materials related to the construction and operation of the Caliente or Mina rail alignment are included in the impacts discussion in Chapter 6, Section 6.4.1.11 of this SEIS.

Table G-70. Waste volumes shipped for disposal.

Waste material	Volume shipped (cubic meters)
Construction and demolition debris	476,000
Sanitary and industrial waste	100,000
Hazardous waste	8,900
Low-Level radioactive waste	74,000

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Appendix H

Supplemental Transportation
Information

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H. SUPPLEMENTAL TRANSPORTATION INFORMATION

H.1 Introduction

The U.S. Department of Energy (DOE or the Department) developed this appendix to provide general background information on transportation-related topics and to help readers understand how the transportation system would operate within the regulatory framework for the transportation of spent nuclear fuel and high-level radioactive waste. Section H.2 discusses transportation regulations, Section H.3 describes the components of a transportation system, and Section H.4 discusses operational practices. Section H.5 describes cask safety and testing. Section H.6 discusses emergency response, and Section H.7 describes available assistance for state, local, and American Indian tribal governments for emergency response planning. Section H.8 discusses DOE plans for transportation security, and Section H.9 describes potential liability under the *Price-Anderson Act* [Section 170 of the *Atomic Energy Act*, as amended (42 U.S.C. 2011 et seq.)]. Section H.10 presents the National Academy of Sciences findings and recommendations.

Spent nuclear fuel is fuel that has been withdrawn from a nuclear reactor following irradiation, the component elements of which have not been separated by reprocessing. In this document, the term refers to the special nuclear material, byproduct material, source material, and other radioactive materials associated with fuel assemblies and includes commercial spent nuclear fuel (including mixed-oxide fuel) from civilian nuclear power reactors, and DOE spent nuclear fuel from DOE and non-DOE production reactors, naval reactors, test and experimental reactors, and research reactors. Naval spent nuclear fuel shipments to the repository would be conducted under the authority of Presidential Executive Order 12344 and Public Law 106-65 and would be in compliance with applicable sections of the Code of Federal Regulations (CFR).

Most nuclear power reactors use solid uranium dioxide ceramic pellets of low-enriched uranium for fuel. The pellets are sealed in strong metal tubes, which are bundled together to form a nuclear fuel assembly. Depending on the type of reactor, typical fuel assemblies can be as long as 4.9 meters (16 feet) and weigh up to 540 kilograms (1,200 pounds). After a period in a reactor, the fuel is no longer efficient for the production of power, and the assembly is removed from the reactor. After removal, the assembly (now called spent nuclear fuel) is highly radioactive and requires heavy shielding and remote handling to protect workers and the public.

High-level radioactive waste is the highly radioactive material that resulted from the reprocessing of spent nuclear fuel; it includes liquid waste that was produced directly in reprocessing and any solid material from such liquid waste that contains fission products in sufficient concentrations. High-level radioactive waste also includes other highly radioactive material that the U.S. Nuclear Regulatory Commission (NRC), consistent with existing law, has determined by rule to require permanent isolation. Immobilized surplus weapons-usable plutonium is part of the high-level radioactive waste inventory. All high-level radioactive waste would be in a solid form before DOE would ship it to Yucca Mountain.

H.2 Transportation Regulations

The shipment of spent nuclear fuel and high-level radioactive waste is highly regulated. For transportation of these materials to Yucca Mountain, DOE would meet or exceed U.S. Department of

Transportation and NRC regulations. DOE would also work with states, local government officials, federally recognized American Indian tribes, utilities, the transportation industry, and other interested parties in a cooperative manner to develop the transportation system.

The *Hazardous Materials Transportation Act*, as amended (49 U.S.C. 1801 et seq.), directs the U.S. Department of Transportation to develop transportation safety standards for hazardous materials in commerce, including radioactive materials. Title 49 of the CFR contains U.S. Department of Transportation standards and requirements for the packaging, transporting, and handling of radioactive materials for all modes of transportation. NRC sets additional design and performance standards for packages that carry materials with higher levels of radioactivity.

The *Nuclear Waste Policy Act*, as amended (NWPA) (42 U.S.C. 10101 et seq.), requires that all shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain be in NRC-certified casks and abide by NRC regulations related to advance notification of state and local governments. This section discusses the key regulations that govern the transportation of spent nuclear fuel and high-level radioactive waste.

H.2.1 PACKAGING

The primary means for the protection of people and the environment during radioactive materials shipment is the use of radioactive materials packages that meet U.S. Department of Transportation and NRC requirements. Packages are selected based on activity, type, and form of the material to be shipped. Pursuant to Section 180(a) of the NWPA, all shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be in packages certified for such purposes by the NRC. All spent nuclear fuel and high-level radioactive waste shipments to Yucca Mountain would be in Type B casks, which have the most stringent design standards to prevent release of radioactive materials under normal conditions of transport and during hypothetical accidents (Section H.4.10 discusses off-normal conditions). NRC regulates and certifies the design, manufacture, testing, and use of Type B packages under regulations in 10 CFR Part 71. All shippers must properly package radioactive materials so that external radiation levels do not exceed regulatory limits. The packaging protects handlers, transporters, and the public from exposure to dose rates in excess of recognized safe limits. Regulations in 10 CFR 71.47 and 49 CFR 173.441 prescribe the external radiation standards for all packages. For shipments to the repository, the limiting radiation dose limit would be 10 millirem per hour at any point 2 meters (6.6 feet) from the outer edge of the railcar or truck trailer.

H.2.2 MARKING, LABELING, AND PLACARDING

U.S. Department of Transportation regulations in 49 CFR require that shippers meet specific hazard communication requirements in marking and labeling packages that contain radioactive materials and other hazardous materials. Markings, labels, and placards identify the hazardous contents to emergency responders in the event of an incident.

Markings provide the proper shipping name, a four-digit hazardous materials number, the shipper's name and address, gross weight, and type of packaging; other important information labels on opposite sides of a package identify the contents and radioactivity level. Shippers of radioactive materials use one of three labels—Radioactive White I, Yellow II, or Yellow III—as shown in Figure H-1. The use of a particular label is based on the radiation level at the surface of the package and the transport index. The transport index, determined in accordance with 49 CFR 173.403, is a number on the label of a package that indicates the degree of control the carrier must exercise during shipment. Packaging that previously contained Class 7 (radioactive) materials and has been emptied of its contents as much as practicable is exempted from marking requirements. However, 49 CFR 173.428 requires the application of an Empty label (not shown) to the cask.

Figure H-1 also shows a Fissile label, which shippers must apply to each package with fissile material (a material that is capable of sustaining a chain reaction of nuclear fission). Such labels, where applicable, must be affixed adjacent to the labels for radioactive materials. The Fissile label includes the Criticality Safety Index, which indicates how many fissile packages can be grouped together on a conveyance.

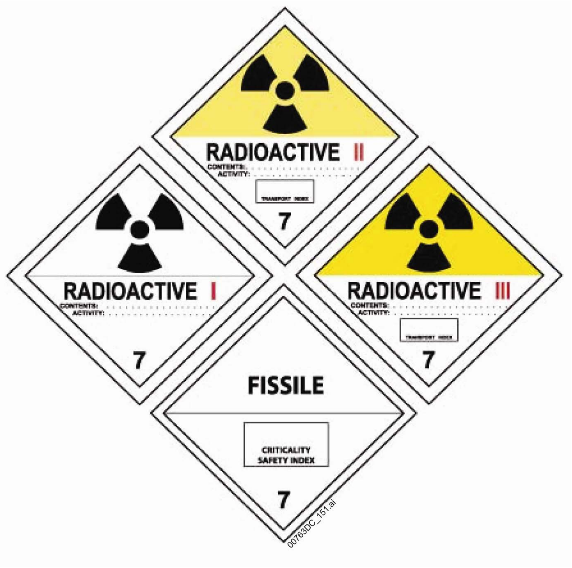


Figure H-1. Radioactive material shipment labels.

Shipments of spent nuclear fuel and high-level radioactive waste are usually classified as Highway Route-Controlled Quantities of Radioactive Materials, and 49 CFR 172.403(c) requires Radioactive Yellow III labels for them regardless of the radiation dose rate. For Radioactive Yellow III shipments, 49 CFR 172.504 requires radioactive hazard communication placards (Figure H-2) on each side and each end of a freight container, transport vehicle, or railcar. In addition, for Highway Route-Controlled Quantities of Radioactive Materials shipments the placard must be on a white square background with a black border (49 CFR 172.507 through 172.527). In addition to the placard, a vehicle might have a United Nations Identification Number near the placard. The United Nations assigns these four-digit numbers, which shippers commonly use throughout the world to aid in the quick identification of materials in bulk containers. The number appears on either an orange plane or on a plain white square-on-point configuration similar to a placard. The usual identification number for spent nuclear fuel is UN3328.

Figure H-2. Radioactive hazard communication placard.

H.2.3 SHIPPING PAPERS

The shipper prepares shipping papers and gives them to the carrier. These documents contain additional details about the cargo and include a signed certification that the material is properly classified and in proper condition for transport. Shipping papers also contain emergency information that includes contacts and telephone numbers. Highway carriers must keep shipping papers readily available during transport for inspection by appropriate officials such as state or federal inspectors.

H.2.4 ROUTING

In accordance with U.S. Department of Transportation regulations, shipments of Highway Route-Controlled Quantities of Radioactive Materials, such as spent nuclear fuel and high-level radioactive waste, would be shipped using preferred routes that reduce time in transit [49 CFR 397.101(b)]. A preferred route is an Interstate system highway, including beltways and bypasses or an alternative route selected by a state or tribal routing agency in accordance with 49 CFR 397.103 using *Guidelines for Selecting Preferred Highway Routes for Highway Route-Controlled Quantity Shipments of Radioactive Materials* or an equivalent routing analysis that adequately considers overall risk to the public. Factors for analysis by the state or tribal routing agency can include accident rates, traffic counts, distance, vehicle speeds, population density, land use, timeliness, and availability of emergency response capabilities. Substantive consultation with affected jurisdictions is required prior to designating an alternative route to ensure consideration of all impacts and continuity of designated route. U.S. Department of Transportation highway routing regulations preempt any conflicting routing requirements that state, local, or tribal governments might issue, such as prohibitions on radioactive waste shipments through local nuclear-free zones (49 CFR 397.203).

Railroads are privately owned and operated, and shippers and rail carriers determine routes based on a variety of factors. Route selection for shipments to Yucca Mountain would involve discussions between DOE and the chosen rail carriers, with consideration of input from other stakeholders. Federal rules do not prescribe specific routes for spent nuclear fuel and high-level radioactive waste shipments by rail, although certain factors, as described below, must be considered in route selection.

The U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration, in coordination with the Federal Railroad Administration and the Transportation Security Administration, has issued an Interim Final Rule revising requirements in the Hazardous Materials Regulations applicable to the safe and secure transportation of certain hazardous materials transported in commerce by rail (71 FR 20752, April 16, 2008). The rule encompasses, among other materials, Highway Route-Controlled Quantities of Class 7 (Radioactive) Material, as defined by 49 CFR 173.403, that are transported by rail. The Interim Final Rule requires rail carriers to compile annual data on these shipments, use the data to analyze safety and security risks along rail routes where those materials are transported, assess alternative routing options, and make routing decisions based on those assessments to select the safest and most secure practicable route. Many factors are to be considered in the safety and security risk analysis of routes, including rail traffic density, time and distance in transit, track class and conditions, environmentally-sensitive or significant areas, population density, emergency response capability, past incidents, availability of practicable alternatives, and other factors.

The U.S. Coast Guard issues regulations regarding the movement of barge shipments of spent nuclear fuel and high-level radioactive waste, including the use of particular facilities, waterways, and vessel and port security procedures. Handling regulations specific to spent nuclear fuel are found at 33 CFR Part 126. The Coast Guard also designates safety zones and security zones that may apply to a specific port, facility, or waterway, or may describe a zone of exclusion around a moving vessel (33 CFR Part 165). The DOE would meet or exceed these regulatory standards.

H.2.5 ADVANCE NOTIFICATION

As required by Section 180(b) of the NWPA, all shipments to a repository would abide by NRC regulations on advance notification of state and local governments. NRC regulations (10 CFR Part 73) provide for written notice to governors or their designees in advance of irradiated reactor fuel shipments through their states. The NRC regulations allow states to release certain advance information to local officials on a need-to-know basis. In 1998 DOE requested that the NRC amend its regulations to permit notification to tribal authorities in addition to states. This would enable the Office of Civilian Radioactive Waste Management to provide advance notification to tribes of repository shipments, consistent with current DOE policies and practices for other types of radioactive shipments that are not subject to the NWPA.

NRC issued an "Advance Notice of Proposed Rulemaking" (64 FR 71331) on December 21, 1999, to invite early input from affected parties and the public on advance notification to American Indian tribes of spent nuclear fuel and high-level waste shipments. Although the Commission approved a rulemaking plan, it put the rulemaking on hold pending review of Commission rules in response to the events of September 11, 2001. NRC is coordinating the schedule for this rulemaking with other security rulemaking activities. The current schedule would result in a proposed rule in about 2010. Notification of shipments to a repository would be in accordance with NRC regulations in effect at that time.

In accordance with NRC regulations, DOE Manual 460.2-1, *Radioactive Material Transportation Practices Manual for Use with DOE O 460.2A* (DIRS 171934-DOE 2002, all) requires written notice to governors or their designees before shipment of spent nuclear fuel and high-level radioactive waste through their states in a manner consistent with the requirements, as applicable, of 10 CFR 71.97 and 73.37. If sent by regular mail, the notice must be postmarked at least 7 days before the shipment enters the state; for messenger service, it must arrive 4 days before. The notification must contain the name, address, and telephone number of the shipper, the carrier, and the receiver; a description of the shipment; a list of the routes within the state; the estimated date and time of departure from the point of origin; the estimated date and time of entry into the state; and a statement on safeguarding schedule information. In the event of a change in schedule that differed more than 6 hours from what was in the notification to the governor or designee, DOE would provide the state with the new schedule by telephone.

H.2.6 RAILROAD SAFETY PROGRAM

The *Rail Safety Act of 1970* (Public Law 91-458) authorized states to work with the Federal Railroad Administration to enforce federal railroad safety regulations. States can enforce federal standards for track, signal and train control, motive power and equipment, and operating practices. In 1992, the State Safety Participation regulations (49 CFR Part 212) were revised to permit states to perform hazardous materials inspections of rail shipments. The Grade Crossing Signal System Safety regulations (49 CFR Part 234) were revised to authorize federal and state signal inspectors to ensure that railroad owners or operators were properly testing, inspecting, and maintaining automated warning devices at grade crossings. Before state participation can begin, each state agency must enter into a multiyear agreement with the Federal Railroad Administration for the exercise of specified authority. This agreement can delegate investigative and surveillance authority in relation to all or any part of federal railroad safety laws.

H.2.7 PERSONNEL TRAINING

U.S. Department of Transportation regulations require proper training for anyone involved in the preparation or transportation of hazardous materials, including radioactive materials. In accordance with 49 CFR Part 397, Subpart D, operators of vehicles that transport Highway Route-Controlled Quantities of Radioactive Materials receive special training that covers the properties and hazards of the materials, associated regulations, and applicable emergency procedures. In addition, DOE Orders require that driver or crew training covers operation of the specific package tie-down systems, cask recovery procedures, use of radiation detection instruments, use of satellite tracking systems and other communications equipment, adverse weather and safe parking procedures, public affairs awareness, first responder awareness [29 CFR 1910.120 (q)], and radiation worker "B" (or equivalent) training.

The U.S. Department of Transportation also requires training specific to the mode of transportation. Highway carriers are responsible for the development and maintenance of a qualification and training program that meets Department of Transportation requirements. Rail carriers must comply with Federal Railroad Administration regulations. Rail carriers are responsible for training and qualification of their crews, which includes application of 49 CFR Part 240 for locomotive engineer certification. If DOE decided to provide federal rail crews for waste shipments on the national rail system, the carriers would require a pilot, who would be an engineer familiar with the rail territory, unless the federal engineer was qualified on that route. The Federal Railroad Administration requires recurrent and function-specific training for personnel who perform specific work, such as train crews, dispatchers, and signal maintainers. In addition, the regulations require that each employee receive training that specifically addresses the job function.

H.2.8 OTHER REQUIREMENTS

Organizations that represent different transportation modes often establish mode-specific standards. For example, all North American shipments by rail that change carriers must meet Association of American Railroads interchange rules. Equipment in interchanges must also meet the requirements of the *Association of American Railroads Field Manual of Interchange Rules* (DIRS 175727-AAR 2005, all).

On May 1, 2003, the Association released Standard S-2043, *Performance Specification for Trains Used To Carry High-Level Radioactive Material* (DIRS 166338-AAR 2003, all) to establish performance guidelines and specifications for trains that carry spent nuclear fuel or high-level radioactive waste. These guidelines apply to the individual railcars within the train, and they promote communication among railroads, spent nuclear fuel and high-level radioactive waste shippers, and railcar suppliers. The objectives of this standard are (1) to provide a cask, railcar, and train system that ensures safe transportation of casks in the railroad operating environment and allows timetable speeds with limited restrictions and (2) to use the best available technology to minimize the chances of derailment in transportation. This standard reflects the current technical understanding of the railroad industry in relation to optimum vehicle performance through application of current and prospective new railcar technologies. On December 20, 2005, the Association adopted two appendices to AAR S-2043: Appendix A, "Maintenance Standards and Recommended Practices for Trains Used To Carry High-Level Radioactive Material," and Appendix B, "Operating Standard for Trains Used To Carry High-Level Radioactive Material." Changes and additions to this standard can be expected as specific vehicles are developed. All future changes will be based on the achievement of optimum performance within acceptable expectations for safe operations.

Association of American Railroads Circular No. OT-55-I, *Recommended Railroad Operating Practices for Transportation of Hazardous Materials* (DIRS 183011-AAR 2006, all), provides recommendations on operating practices that are adopted by Association of American Railroads and American Short Line and Regional Railroad Association members in the United States for these shipments. The current revision of the circular became effective July 17, 2006; its recommendations cover road operating practices, yard operating practices, storage and separation distances, transportation community awareness and emergency response program implementation, criteria for shipper notification, time-sensitive materials, and special provisions for spent nuclear fuel and high-level radioactive waste.

The Commercial Vehicle Safety Alliance has developed inspection procedures and out-of-service criteria for commercial highway vehicles that transport shipments of transuranic elements and Highway Route-Controlled Quantities of Radioactive Materials shipments (Section H.4.9). Under these procedures, each state through which a shipment passed would inspect each shipment to the repository, and a shipment would not begin or continue until inspectors determined that the vehicle and its cargo were free of defects.

Trucks that carry spent nuclear fuel or high-level radioactive waste and weigh over 36,300 kilograms (80,000 pounds) would exceed federal commercial vehicle weight limits for nondivisible loads (which cannot be separated into smaller loads). Most states require transportation companies to obtain permits when their vehicles exceed weight limits to control time and place of movement. Local jurisdictions also often require overweight permits. The criteria for the permitting process are not uniform among different jurisdictions. A number of factors affect issuance of these permits including traffic volumes and patterns, protection of state highways and structures such as bridges, zoning and general characteristics of the route, and safety of the motoring public.

H.2.9 PROPOSED RAIL REGULATION

The Transportation Security Administration has proposed that freight rail carriers and certain facilities that handle hazardous materials be able to report, upon request, location and shipping information to the Administration and that they should implement chain-of-custody requirements to ensure a positive and secure exchange of specified hazardous materials (71 FR 76852, December 21, 2006). The proposal would clarify and extend the sensitive security information protections to cover certain information associated with rail transportation.

H.3 Transportation System Components

The DOE transportation system would consist of hardware (shipping containers, handling equipment, railcars, and truck trailers), a transportation operations center, a Cask Maintenance Facility, and the Nevada railroad.

H.3.1 TRANSPORTATION CASKS

Pursuant to Section 180(a) of the NWPA, all shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be in packages certified for such purposes by the NRC. The casks would be sealed containers that could weigh up to 180 metric tons (200 tons). The casks would consist of layers of steel and lead or other materials that would provide shielding against the radiation from the waste and prevent the materials from escaping to the environment in the event of an incident.

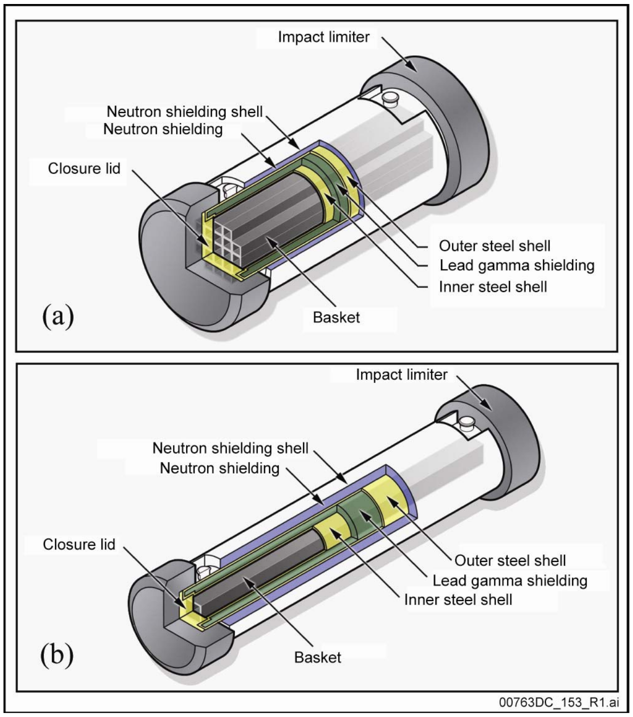


Figure H-3. Generic rail cask (a) and truck cask (b) for spent nuclear fuel.

The open end of the cylindrical cask would be sealed with a heavy lid. Impact limiters on each end of the cask would absorb most of the impact force and provide protection of the container and its contents in the event of an incident. Figure H-3 illustrates generic rail and truck casks.

H.3.2 RAILCARS

The trains DOE would use to transport spent nuclear fuel and high-level radioactive waste to the repository would typically use locomotives, escort cars, one or more loaded cask railcars, and buffer railcars that would separate the cask railcars from occupied locomotives and escort railcars.

H.3.3 TRANSPORTATION OPERATIONS CENTER

The functions of a transportation operations center would include coordination between shipping sites and the repository, planning and scheduling of shipments, coordination with carriers, notifications to states and American Indian tribes, monitoring and tracking of shipments, en route communications, emergency management, and security coordination.

H.3.4 CASK MAINTENANCE FACILITY

Transportation casks and the associated equipment (for example, personnel barriers and impact limiters) must be maintained in proper condition to satisfy the requirements in their NRC certificates of compliance. At the Cask Maintenance Facility, casks would periodically be removed from service for maintenance and inspection. The activities at the Cask Maintenance Facility would include but not be limited to testing, repairs, minor decontamination, and making approved modifications. The Cask Maintenance Facility would also serve as the primary recordkeeping facility for the cask fleet equipment.

H.3.5 TRANSPORT SERVICES

The United States freight railroad system consists of seven Class 1 railroads (mainline), 31 regional railroads, and over 500 local railroads (line-haul railroads smaller than regional railroads). DOE would use short-line or Class 1 railroads to transport casks from the origin sites. There are numerous short-line railroads that operate one or more relatively small sections of track that connect to the Class 1 rail network. Not all origin sites of spent nuclear fuel and high-level radioactive waste have rail services. Origin sites without rail service would require alternative intermodal delivery from the origin site to a nearby rail transfer facility, either by barge using a nearby dock or by heavy-haul truck using local highways.

At some sites with limited cask handling capability, DOE could use overweight trucks for smaller casks. After loading and preparation, DOE would pick up the cask and deliver it directly to the repository using the public highway network.

DOE would construct a railroad to transport casks from a Union Pacific mainline in Nevada to the repository site, and the Department would contract the operation and maintenance of the railroad.

H.4 Operational Practices

DOE has adopted as policy the practices that were developed in consultation with stakeholders and are outlined in DOE Manual 460.2-1 (DIRS 171934-DOE 2002, all). The Manual establishes 14 standard transportation practices for Departmental programs to use in the planning and execution of shipments of radioactive materials including radioactive waste. It provides a standardized process and framework for planning and for interacting with state and tribal authorities and transportation contractors and carriers.

H.4.1 STAKEHOLDER INTERACTIONS

The *Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain: A Guide to Stakeholder Interactions* (DIRS 172433-DOE 2003, all) guides state and tribal government interactions, some of which are already underway. During planning and actual transportation operations, stakeholders are and would continue to be involved in planning for route identification, funding approaches for emergency response planning and training, understanding safeguards and security requirements, operational practices, communications, and information access.

DOE is working collaboratively with states through State Regional Group committees, whose members are state officials responsible for transportation policy, law enforcement, emergency response, and oversight of hazardous materials shipments, and with American Indian tribal governments to assist them to prepare for the shipments.

In addition to coordination with State Regional Group committees and tribal governments, a national cooperative effort is underway as part of DOE's Transportation External Coordination Working Group, which involves a broad range of stakeholder organizations that routinely interact with DOE to provide input and recommendations on transportation planning and program information. DOE works with states, tribes, and industry to guide and focus emergency training, coordination with local officials, and other activities to prepare for shipments to the repository.

DOE is preparing a comprehensive national spent fuel transportation plan that will accommodate stakeholder concerns to the extent practicable. The plan will outline the challenges and strategies for the development and implementation of the system required to transport the waste to Yucca Mountain.

H.4.2 ROUTE PLANNING PROCESS

An initial step in the planning process to ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be to identify a national suite of routes, both rail and highway. DOE is working with stakeholder groups in the process of examining potential routing criteria in the route identification process. State Regional Group committees, tribal governments, transportation associations, industry, federal agencies, and local government organizations are some of the groups that work collaboratively with DOE in this process. DOE is performing and would continue to perform the work through a Topic Group of the Transportation External Coordination Working Group, and intends to seek broader public input and collect comments on routing criteria and the process for development of a suite of routes. The process includes consideration of relevant regulations, industry practices, DOE requirements, and analysis of regional routes that states have previously evaluated in the process to identify a preliminary set of routes. DOE considers public involvement to be an essential element of a safe, efficient, and flexible transportation system.

H.4.3 PLANNING AND MOBILIZATION

DOE would use the methods and requirements this section describes to establish the baseline operational organization and practices for route identification, fleet planning and acquisition, carrier interactions, and operations.

DOE would develop a Transportation Operations Plan to provide the basis for planning shipments. This plan would describe the operational strategy and delineate the steps to ensure compliance with applicable regulatory and DOE requirements. It would include information on organizational roles and responsibilities, shipment materials, projected shipping windows, estimated numbers of shipments, carriers, packages, sets of routes, prenotification procedures, safe parking arrangements, tracking systems, security arrangements, public information, and emergency preparedness, response, and recovery.

The Department would develop individual site plans to include the information necessary to ship from specific sites. The plans would include roles and responsibilities of the participants in the shipping campaign, shipment materials, schedules, number of shipments, types and number of casks and other equipment, carriers, routes, in-transit security arrangements, safe parking arrangements for rail and truck shipments, communications including prenotification, public information, tracking, contingency planning, and emergency preparedness, response, and recovery.

In addition, DOE would issue an Annual Shipment Projection at least 6 months to a year in advance of the beginning of a shipment year and would identify the sites from which it would ship spent nuclear fuel and high-level radioactive waste in a given calendar year, the expected characteristics and quantities of waste to be delivered by each site, types of casks, and anticipated numbers of casks and shipments. The Annual Shipment Projection would not define specific shipment schedules or routes, but DOE would use it for schedule and route planning.

H.4.4 DEDICATED TRAIN SERVICE POLICY

On July 18, 2005, in a policy statement (DIRS 182833-Golan 2005, all), DOE decided that dedicated train service would be the usual manner of rail shipment of commercial and most DOE spent nuclear fuel and high-level radioactive waste to Yucca Mountain. Dedicated train service means train service for one commodity (in this case, spent nuclear fuel and high-level radioactive waste). Past and current shipping campaigns have used dedicated train service to address issues of safety, security, cost, and operations. Analyses indicate that the primary benefit of dedicated train service would be significant cost savings over the lifetime of transportation operations. The added cost of dedicated train service would be offset by reductions in fleet size and its attendant operations and maintenance costs. In addition, the shorter times in transit and shorter layovers at switching yards would enhance safety and security. Use of dedicated train service would provide greater operational flexibility and efficiency because of the reduced transit time and greater predictability in routing and scheduling.

H.4.5 TRACKING AND COMMUNICATION

DOE would provide authorized state and tribal governments with the capability and training to monitor shipments to the repository through their jurisdictions using a satellite tracking system, such as the Transportation Tracking and Communication System, that would provide continuous, centralized monitoring and communications capability (DIRS 172433-DOE 2003, p. 5). Trained personnel could use such a system to monitor shipment progress and communicate with the dispatch center. A transportation operations center would be in contact with the carriers and the escorts throughout each shipment. In addition, all truck and rail escort cars would have communications equipment. The train control center would manage rail communications and signaling on the branch Nevada railroad.

DOE would develop detailed backup procedures to ensure safe operations in the event that the tracking system was temporarily unavailable. The procedures would be based on a telephone call-in system for operators to report shipment locations to DOE on a regular basis and before crossing state and tribal borders.

H.4.6 TRANSPORTATION OPERATIONAL CONTINGENCIES

DOE would obtain weather forecasts along routes as part of preshipment planning, notification, and dispatching. At the time of departure, current weather conditions, the weather forecast, and expected travel conditions would have to be acceptable for safe operations. If these conditions were not acceptable, DOE could delay the shipment until travel conditions became acceptable or reroute the shipment.

Shipments would not travel during severe weather or other adverse conditions that could make travel hazardous. DOE would obtain route conditions and construction information that could temporarily affect the planned route through consultation with the railroads and states along the planned route.

States and tribes may provide input on weather conditions, and specific transportation plans developed in the future may provide additional details on the input process. States and tribes may monitor the status of shipments using the satellite tracking system. Rail carriers use train control and monitoring systems to identify the locations of trains and to make informed decisions to avoid or minimize potentially adverse weather or track conditions. Truck dispatch centers and the transportation operations center would coordinate on weather conditions while shipments were en route.

Continuous communications with a transportation operations center would provide advance warning of potential adverse conditions along the route. If the shipment encountered unanticipated severe weather, the operators would contact this center to coordinate routing to a safe stopping area if it became necessary to delay the shipment until conditions improved.

H.4.7 CARRIER PERSONNEL QUALIFICATIONS

Carriers would develop and maintain qualification and training programs that met U.S. Department of Transportation requirements for drivers, operators, and security personnel. For truck drivers, qualifications include being at least 21 years of age, meeting physical standards, having a commercial driver’s license, and successfully completing a road driving test in the shipment vehicle. In addition, drivers must have training on the properties and hazards of the shipment materials as well as the procedures to follow in the event of an emergency. Locomotive engineers must meet the Locomotive Engineer Certification requirements of 49 CFR Part 240, which include completion of an approved training program (Section H.2.7 addresses other training requirements).

H.4.8 NOTICE OF SHIPMENTS

The NRC requires advance notice, en route status, and other pertinent shipment information on DOE shipments (10 CFR Parts 71 and 73). Section H.2.5 addresses advance notification requirements. DOE and authorized stakeholders would use this information to support coordination of repository receipt operations, to support emergency response capabilities, to identify weather or road conditions that could affect shipments, to identify safe stopping locations, to schedule inspections, and to coordinate appropriate public information programs. NRC regulations in 10 CFR Part 73 require that access to and disclosure of Safeguards Information be limited to those with an established need-to-know.

H.4.9 INSPECTIONS

To ensure safety, DOE would inspect shipments when they left their point of origin and when they arrived at the repository to verify vehicle safety and radiological safety of the transportation casks. These inspections would include radiological surveys of radioactive material packages to ensure that they met the radiation level limits of 49 CFR 173.441 and surface contamination limits of 49 CFR 173.443. DOE would inspect rail shipments in accordance with 49 CFR 174.9 and the Federal Railroad Administration High-Level Nuclear Waste Rail Transportation Inspection Policy in Appendix A of *Safety Compliance Oversight Plan for Rail Transportation of High-Level Radioactive Waste and Spent Nuclear Fuel* (DIRS 156703-DOT 1998, all), which includes motive power, signals, track conditions, manifests, and crew credentials. DOE would inspect highway shipments using the enhanced standards of the Commercial Vehicle Safety Alliance, which provide uniform inspection procedures for radiological requirements, drivers, shipping papers, vehicles, and casks (DIRS 175725-CVSA 2005, all).

Although DOE would minimize the number of stops to the extent practicable, under federal regulations, states and tribes could order additional inspections when shipments entered their respective jurisdictions. DOE would attempt to coordinate those inspections with normal crew change locations whenever possible.

In addition, the Interim Final Rule issued by the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (71 FR 20752, April 16, 2008) requires that rail carriers shipping certain hazardous materials, including Highway Route-Controlled Quantities of class 7 (radioactive) material, as defined by 49 CFR 173.403, conduct inspections of railcars for signs of tampering or suspicious items.

H.4.10 PROCEDURES FOR OFF-NORMAL CONDITIONS

Off-normal conditions are potentially adverse conditions that do not relate to accidents, incidents, or emergencies. They include but are not limited to mechanical breakdowns, fuel problems, tracking system failure, and illness, injury, or other incapacity of a member of the truck, train, or escort crew. DOE would require carriers to provide operators with specific written procedures that define detailed actions for off-normal events. Procedures would address notifications, deployment of appropriate hazard warnings, security, medical assistance, operator or escort replacement, and maintenance, repair, replacement, or recovery of equipment, as appropriate. Procedures would also cover selection of alternative routes and safe parking areas.

H.4.11 POSTSHIPMENT RADIOLOGICAL SURVEYS

DOE would visually inspect and radiologically survey the external surfaces of a cask after shipment in accordance with U.S. Department of Transportation, DOE, and NRC regulations. Receiving facility operators would survey each cask and transporter on arrival (before unloading) and determine if there was radiological contamination in excess of the applicable limits. The inspections would include the cask, tie-downs, and associated hardware to determine if physical damage occurred during transit.

H.4.12 SHIPMENT OF EMPTY TRANSPORT CASKS

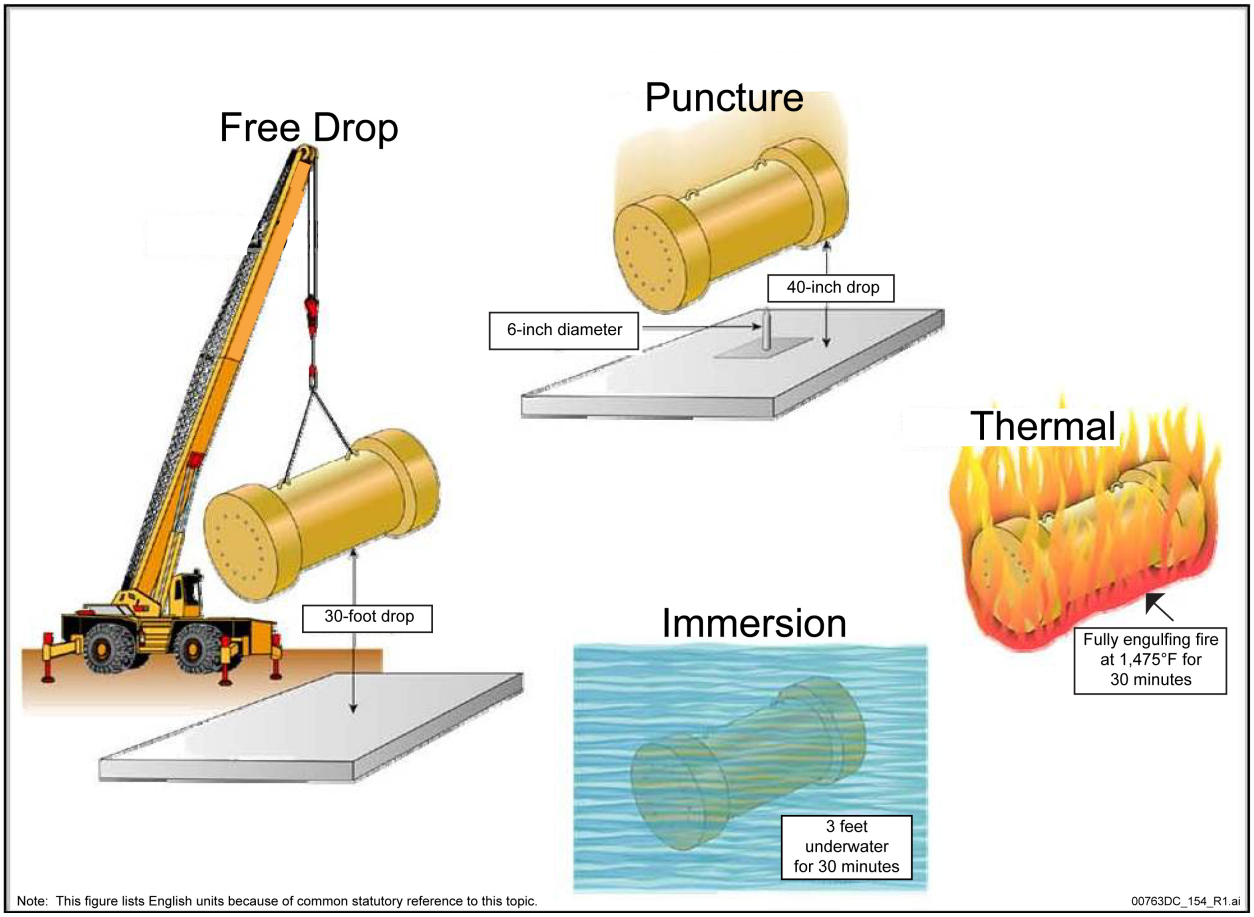
Except before their first use, shipments of all empty transportation casks would comply with the requirements of the NRC certificate of compliance or 49 CFR 173.428, which addresses empty radioactive materials packages, whichever was applicable. DOE would ship casks that did not meet the criteria for “empty” in accordance with the applicable U.S. Department of Transportation hazardous materials regulations. Advance shipment notifications and en route inspections would not apply to the shipment of empty transportation casks; however, DOE would use dedicated train service to realize the cost benefits of a decreased fleet requirement.

H.5 Cask Safety

The purpose of the NRC regulations for transportation of spent nuclear fuel and high-level radioactive waste (10 CFR Part 71) is to protect the public health and safety from normal and off-normal conditions of transport and to safeguard and secure shipments of these materials. Over the years, NRC has amended its regulations to be compatible with the latest editions of the International Atomic Energy Agency and other standards (69 FR 3698, January 26, 2004).

In addition to the standard testing discussed below, NRC has committed to a package performance study for the full-scale testing of a spent nuclear fuel package of the kind DOE would likely use. The Commission approved the proposed test in June 2005 (DIRS 182896-Vietti-Cook 2005, all; DIRS 182897-Reyes 2005, all). According to the proposal, the package would contain surrogate fuel elements and be mounted on a railcar placed at 90 degrees to a simulated rail crossing. The rail package would be subjected to a collision with a locomotive and several freight cars at 96 kilometers (60 miles) per hour. NRC is formulating the study to give the public greater confidence in the movement of spent nuclear fuel, to provide information on the methods and processes of transportation system qualification, and to validate the applicability of NRC regulations.

Regulations in 10 CFR Part 71 require that casks for shipping spent nuclear fuel and high-level radioactive waste must be able to meet specified radiological performance criteria for normal transport and for transport under severe accident conditions. Meeting these requirements is an integral part of the safety assurance process for transportation casks. The ability of a design to withstand these conditions can be demonstrated by comparing designs of similar casks, performing engineering analyses (such as computer-simulated tests), or by conducting scale-model or full-scale testing. As shown in Figure H-4, these hypothetical accident conditions include, in sequence, a 9-meter (30-foot) drop onto an unyielding



Note: This figure lists English units because of common statutory reference to this topic.

Figure H-4. Hypothetical accident conditions.

flat surface, a 1-meter (40-inch) drop onto a vertical steel bar, exposure of the entire package to fire for 30 minutes, and immersion in 0.9 meter (3 feet) of water. In addition, an undamaged cask must be able to survive submersion in the equivalent pressure of 15 and 200 meters (50 and 650 feet) of water.

For most accidents more severe than those the hypothetical accident conditions simulate, NRC studies (DIRS 152476-Sprung et al. 2000, all; DIRS 181841-Adkins et al. 2007, all; DIRS 182014-Adkins et al. 2006, all) show that the radiological criteria for containment, shielding, and subcriticality would still be satisfied. The studies also show that for the few severe incidents in which these criteria could be exceeded, only containment and shielding would be affected, and the regulatory criteria could be exceeded only slightly. Based on the analyses of the *Final Environmental Impact Statement for a Geological Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS), casks would continue to contain spent nuclear fuel and high-level radioactive waste fully in more than 99.99 percent of all incidents (of the thousands of shipments over the last 30 years, none has resulted in an injury due to the release of radioactive materials). The following sections discuss each of these packaging performance criteria.

H.5.1 NINE-METER DROP ONTO AN UNYIELDING SURFACE

The first set of accident conditions in the sequence simulates impact and evaluation of a 9-meter (30-foot) free fall onto an unyielding surface with the cask striking the target in the most damaging orientation. The free fall results in a final velocity of 48 kilometers (30 miles) per hour. Although this velocity is less than the expected speed of interstate highway traffic, it is severe because the target surface is unyielding. This results in the cask absorbing all the energy of the drop, which is approximately equivalent to a 96-kilometer (60-mile)-per-hour impact with a medium hardness surface (such as shale or other relatively soft rock) and a 145-kilometer (90-mile)-per-hour impact with a soft surface (such as tillable soil).

H.5.2 ONE-METER DROP ONTO A STEEL BAR

The second set of accident conditions simulates a cask hitting a rod or bar-like object that could be present in an accident. This requires evaluation of a 1-meter (40-inch) drop onto a 15-centimeter (6-inch)-diameter rod on an unyielding surface. The cask must be in the orientation in which maximum damage would be likely. In addition, the bar must be long enough to cause maximum damage to the cask. This evaluates several impacts in which different parts of a cask strike the bar either by simulation or physical testing.

H.5.3 FIRE

The third set of accident conditions simulates a fire that occurs after the two impacts. This involves a hydrocarbon fire with an average flame temperature of 800°C (1,475°F) and requires the cask to be fully engulfed in the flame for 30 minutes.

H.5.4 WATER IMMERSION

The final set of accident conditions in the sequence is shallow immersion. The cask must be immersed in 0.9 meter (3 feet) of water. The purpose of this test is to ensure that water cannot leak into the cask after having passed through the challenges.

An undamaged version of the cask must also be able to survive immersion in the equivalent of 15 meters (50 feet) of water at a pressure of about 1,530 grams per square centimeter (21.7 pounds per square inch) to test for leakage. Furthermore, transportation casks for more than 1 million curies of radioactivity must be able to survive water pressure of about 20,400 grams per square centimeter (290 pounds per square inch) for 1 hour without collapsing, buckling, or leaking. That pressure is equivalent to a depth of about 200 meters (650 feet).

H.5.5 ACCEPTANCE CRITERIA

To be judged successful in meeting all but the 200-meter (650-foot) submersion requirement, a cask must not release more than limited amounts of radioactive material in 1 week. These release limits are set for each radionuclide based on dispersivity and toxicity. In addition, the cask must not emit radiation at a dose rate of greater than 1 rem per hour at a distance of 1 meter (3.3 feet) from the cask surface. Last, the contents of the cask must not be capable of undergoing a nuclear chain reaction, or criticality, as a result of the hypothetical accident conditions.

H.5.6 USE OF MODELS

Manufacturers can demonstrate the ability of a cask to survive these hypothetical accident conditions in several ways. They can subject a full-size model of the cask to the sequences, use smaller models of the casks (typically half- or quarter-scale), compare the cask design to previously licensed designs, or analyze the hypothetical accident scenarios with computer models. NRC approves the level of physical testing or analysis necessary for each cask design. Because the NRC generally accepts the results of scale-model testing, more expensive full-scale testing rarely occurs, although NRC sometimes requires such tests for specific cask components. For example, NRC could accept quarter-scale drop tests for a particular cask design but full-scale tests of the cask's impact limiters. Computer analysis could be sufficient for meeting the hypothetical fire and criticality control criteria.

H.6 Emergency Response

H.6.1 ROLES AND RESPONSIBILITIES

States and tribes along shipping routes have the primary responsibility for the protection of the public and environment in their jurisdictions. If an emergency that involved a DOE radioactive materials shipment occurred, incident command would be established based on the procedures and policies of the state, tribe, or local jurisdiction. When requested by civil authorities, DOE would provide technical advice and assistance including access to teams of experts in radiological monitoring and related technical areas. DOE staffs eight Regional Coordinating Offices 24 hours a day, 365 days a year with teams of nuclear engineers, health physicists, industrial hygienists, public affairs specialists, and other professionals (Section H.6.2 contains further detail on the DOE role). Under NWPA Section 180(c), DOE must provide technical assistance and funds to states for training for public safety officials of appropriate units of local government and American Indian tribes through whose jurisdiction DOE plans to transport spent nuclear fuel or high-level radioactive waste. Training must cover procedures for safe routine transportation of these materials as well as for emergency response situations.

DOE would require selected carriers to provide drivers and train crews with specific written procedures that defined detailed actions for an emergency or incident that involved property damage, injury, or the release or potential release of radioactive materials. Procedures would comply with U.S. Department of Transportation guidelines for emergency response in the *2004 Emergency Response Guidebook* (DIRS 175728-DOT 2004, all) and would address emergency assistance to injured crew or others who were involved in identification and assessment of the situation, notification and communication requirements, securing of the site and controlling access, and technical help to first responders.

H.6.2 FEDERAL COORDINATION

The Department of Homeland Security coordinates the overall Federal Government response to radiological incidents that require a coordinated federal response in accordance with *Homeland Security Presidential Directive/HSPD 5* (DIRS 182271-DHS 2003, all) and the *National Response Framework* (DIRS 185500-DHS 2008, all). Based on Directive 5 criteria, an incident that would require a federal response is an actual or potential high-impact event that requires a coordinated and effective response by, and appropriate combination of, federal, state, local, tribal, nongovernmental, or private-sector entities to save lives and minimize damage, and to provide the basis for long-term community recovery and mitigation activities.

In HSPD-5, the President designates the Secretary of Homeland Security as the Principal Federal Official for domestic incident management and empowers the Secretary to coordinate federal resources used in response to terrorist attacks, major disasters, or other emergencies in specific cases (DIRS 182271-DHS 2003, all). The Directive establishes a single, comprehensive National Incident Management System that unifies federal, state, territorial, tribal, and local lines of government into one coordinated effort. This system encompasses much more than the Incident Command System, which is nonetheless a critical component of the National Incident Management System. That system also provides a common foundation for training and other preparedness efforts, communicating and sharing information with other responders and with the public, ordering resources to assist with a response effort, and integrating new technologies and standards to support incident management. The Incident Command System uses as its base the local first responder protocols; that use does not eliminate the required agreements and coordination among all levels of government.

In HSPD-5 (DIRS 182271-DHS 2003, all), the President directed the development of the new *National Response Framework* (DIRS 185500-DHS 2008, all) to align federal coordination structures, capabilities, and resources into a unified approach to domestic incident management. The Plan is built on the template of the National Incident Management System. The Plan provides a comprehensive, all-hazards approach to domestic incident management. All federal departments and agencies must adopt the National Incident Management System and use it in their individual domestic incident management and emergency prevention, preparedness, response, recovery, and mitigation activities, as well as in support of all actions taken to assist state or local entities.

DOE supports the Department of Homeland Security as the coordinating agency for incidents that involve the transportation of radioactive materials by or for DOE. DOE is otherwise responsible for the radioactive material, facility, or activity in the incident. DOE is part of the Unified Command, which is an application of the Incident Command System for when there is more than one agency with incident jurisdiction or when incidents cross political jurisdictions. DOE coordinates the federal radiological response activities as appropriate. Agencies work together through the designated members of the Unified Command, often the senior person from agencies or disciplines that participate in the Unified Command, to establish a common set of objectives and strategies.

DOE, as the transporter of radiological material, would notify state and tribal authorities and the Homeland Security Operations Center. The Department of Homeland Security and DOE coordinate federal response and recovery activities for the radiological aspects of an incident. DOE reports information and intelligence in relation to situational awareness and incident management to the Homeland Security Operations Center.

The Department of Homeland Security and DOE are responsible for coordination of security activities for federal response operations. While spent nuclear fuel and high-level radioactive waste shipments are in transit, state, local, and tribal governments could provide security for a radiological transportation incident that occurred on public lands. The Department of Homeland Security, with DOE as the coordinating agency, approves issuance of all technical data to state, local, and tribal governments.

The Interagency Modeling and Atmospheric Assessment Center is responsible for production, coordination, and dissemination of consequence predictions for an airborne hazardous material release. The Center generates the single federal prediction of atmospheric dispersions and their consequences using the best available resources.

Federal monitoring and assessment activities are coordinated with state, local, and tribal governments. Federal agency plans and procedures for implementation of this activity are designed to be compatible with the radiological emergency planning requirements for state and local governments, specific facilities, and existing memoranda of understanding and interagency agreements.

DOE maintains national and regional coordination offices at points of access to federal radiological emergency assistance. Requests for Radiological Assessment Program teams go directly to the DOE Emergency Operations Center in Washington, D.C. If the situation requires more assistance than a team can provide, DOE alerts or activates additional resources. DOE can respond with additional resources including the Aerial Measurement System to provide wide-area radiation monitoring and Radiation Emergency Assistance Center/Training Site medical advisory teams. Some participating federal agencies have radiological planning and emergency responsibilities as part of their statutory authority, as well as established working relationships with state counterparts. The monitoring and assessment activity, which DOE coordinates, does not alter these responsibilities but complements them by providing coordination of the initial federal radiological monitoring and assessment response activities.

The Department of Homeland Security and DOE, as the coordinating agency, oversee the development of Federal Protective Action Recommendations. In this capacity, the departments provide advice and assistance to state, tribal, and local governments, which can include advice and assistance on measures to avoid or reduce exposure of the public to radiation from a release of radioactive material and advice on emergency actions such as sheltering and evacuation.

State, local, and tribal governments are encouraged to follow closely the *National Response Framework* (DIRS 185500-DHS 2008, all), the Nuclear/Radiological Incident Annex, and the National Incident Management System protocols and procedures. As established, all federal, state, local, and tribal responders agree to and follow the Incident Command System.

H.7 Technical Assistance and Funding for Training of State and American Indian Public Safety Officials

The NWPA requires DOE to provide technical assistance and funds to states for training for public safety officials of appropriate units of local government and Indian tribes through whose jurisdictions the Department plans to transport spent nuclear fuel or high-level radioactive waste to a repository. Section 180(c) further provides that training must cover procedures for safe route transportation of these materials as well as for emergency response situations. Section 180(c) encompasses all modes of transportation, and funding would come from the Nuclear Waste Fund. Once implemented, this program would provide funding and technical assistance to train firefighters, law enforcement officers, and other public safety officials in preparation for repository shipments through their jurisdictions.

To implement this requirement, in the 1990s DOE published four *Federal Register* notices to solicit public comment on its approach to implementing Section 180(c). DOE responded to the comments in subsequent notices through April 1998. In 2004, DOE determined that is was timely to update its proposed policy for implementing Section 180(c).

The revisitation of Section 180(c) implementation began with the formation of a Transportation External Coordination Working Group Topic Group in April 2004. DOE also worked with State Regional Group committees and the Tribal Topic Group of the Transportation External Coordination Working Group to solicit stakeholder input on the policy. Topic Group members wrote issue papers on specific Section 180(c) topics such as allowable activities, funding allocation method, timing and eligibility, and definitions. Based on consideration of these materials, DOE developed a revised proposed policy that it issued in a *Federal Register* notice on July 23, 2007 (72 FR 40139) to request additional comments from stakeholders and the public. DOE plans to conduct a pilot program to test implementation of the Section 180(c) grant program prior to issuing the final Section 180(c) policy.

Pursuant to DOE's proposed policy, Section 180(c) funds would be intended for training specific to shipments of spent nuclear fuel and high-level radioactive waste to a repository. DOE would work with states and tribes to evaluate current preparedness for safe routine transportation and emergency response capability and would provide funding as appropriate to ensure that state, tribal, and local officials are prepared for such shipments. Section 180(c) funds would be intended to supplement but not duplicate existing training for safe routine transportation and emergency preparedness. DOE would work with states and tribes to coordinate and integrate Section 180(c) activities with existing training programs designed for state, tribal, and local public safety officials. Subject to the availability of appropriated funds, DOE anticipates making two types of grants available to eligible states and tribes. An initial assessment and planning grant would be available approximately 4 years prior to the commencement of shipments through a state or tribe's jurisdiction to support assessing the need for and planning for training. Subsequently, DOE intends to issue training grants in each of the 3 years prior to a scheduled shipment through a state or tribe's jurisdiction and every year that shipments are scheduled. Since state and tribal governments have primary responsibility to protect the public health and safety in their jurisdictions, they would have flexibility to decide for which allowable activities to request Section 180(c) assistance to meet their unique needs. States and tribes would be expected to coordinate with local public safety officials and to describe in their grant applications how they would use the grants to provide training to local public safety officials. The particular funding allocations would be determined in accordance with the approach in the proposed policy.

H.8 Transportation Security

Transportation safeguards and security are among the highest DOE priorities as it plans for shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain. DOE would build the security program for the shipments on the successful security program it developed and has successfully used in past decades for shipments of spent nuclear fuel to DOE facilities from foreign and domestic reactors.

An effective security program must protect members of the public near transportation routes as well as minimize potential threats to workers, and it must include security elements appropriate to each phase of transportation. DOE would continually test security procedures to identify improvements in the security system throughout transportation operations. The key elements of a secure transportation program include physical security systems, information security, materials control and accounting, personnel security, security program management, and emergency response capabilities.

DOE is working closely with other federal agencies including NRC and the Department of Homeland Security to understand and mitigate potential threats to shipments. In addition to domestic efforts, the Department is a member of the International Working Group on Sabotage for Transport and Storage Casks, which investigates the consequences of a potential act of sabotage and explores opportunities to enhance the physical protection of casks. As a result of these efforts, DOE would modify its methods and systems as appropriate between now and the time of shipments.

In coordination with other federal agencies, DOE is working with stakeholders including state, local, and tribal governments; industry associations such as the Association of American Railroads; and technical advisory and oversight organizations such as the National Academy of Sciences and the Nuclear Waste Technical Review Board. This coordination enables DOE to take advantage of the experience and practical recommendations of experts on a broad range of security-related technical, procedural, and operational matters.

H.9 Liability

The *Price-Anderson Act* provides indemnification for liability for nuclear incidents that apply to the proposed Yucca Mountain Repository. The following sections address specific details or provisions of the Act.

H.9.1 THE PRICE-ANDERSON ACT

In 1957, Congress enacted the *Price-Anderson Act* as an amendment to the *Atomic Energy Act* to encourage the development of a commercial nuclear industry and to ensure prompt and equitable compensation in the event of a nuclear incident. The *Price-Anderson Act* establishes a system of financial protection for persons who could be liable for and persons who could be injured by a nuclear incident. The purposes of the Act are (1) to encourage growth and development of the nuclear industry through the increased participation of private industry and (2) to protect the public by ensuring that funds are available to compensate victims for damages and injuries sustained in the event of a nuclear incident. Congress renewed and amended the indemnification provisions in 1966, 1969, 1975, and 1988. The 1988 *Price-Anderson Amendments Act* extended the Act for 14 years until August 1, 2002 (Public Law 100-408, 102 Stat. 1066). Since then, Congress has extended the Act until December 31, 2025, and increased liability to $10.26 billion for an extraordinary nuclear occurrence (that is, any nuclear incident that causes substantial damage), subject to increase for inflation.

H.9.2 INDEMNIFICATION UNDER THE PRICE-ANDERSON ACT

For each shipper, DOE must include an agreement of indemnification in each contract that involves the risk of a nuclear incident. This indemnification (1) provides omnibus coverage of all persons who could be legally liable, (2) fully indemnifies all legal liability up to the statutory limit on such liability (currently $10.26 billion for a nuclear incident in the United States), (3) covers all DOE contractual activity that could result in a nuclear incident in the United States, (4) is not subject to the usual limitation on the availability of appropriated funds, and (5) is mandatory and exclusive.

H.9.3 COVERED AND EXCLUDED INDEMNIFICATION

The *Price-Anderson Act* indemnifies liability arising out of, or resulting from, a nuclear incident or precautionary evacuation, including all reasonable additional costs incurred by a state or a political subdivision of a state, in the course of responding to a nuclear incident or a precautionary evacuation. It excludes (1) claims under state or federal worker compensation acts of indemnified employees or persons who are at the site of, and in connection with, the activity where the nuclear incident occurs, (2) claims that arise out of an act of war, and (3) claims that involve certain property on the site.

H.9.4 PRICE-ANDERSON ACT DEFINITION OF A NUCLEAR INCIDENT

A nuclear incident is any occurrence, including an extraordinary nuclear occurrence, causing bodily injury, sickness, disease, or death, or loss of or damage to property, or loss of use of property, arising out of or resulting from the radioactive, toxic, explosive, or other hazardous properties of source, special nuclear, or byproduct material (42 U.S.C. 2014).

H.9.5 PROVISIONS FOR PRECAUTIONARY EVACUATION

A precautionary evacuation is an evacuation of the public within a specified area near a nuclear facility or the transportation route in the case of an incident that involves transportation of source material, special nuclear material, byproduct material, spent nuclear fuel, high-level radioactive waste, or transuranic waste. It must be the result of an event that is not classified as a nuclear incident but poses an imminent danger of injury or damage from the radiological properties of such nuclear materials and causes an evacuation. The evacuation must be initiated by an official of a state or a political subdivision of a state who is authorized by state law to initiate such an evacuation and who reasonably determined that such an evacuation was necessary to protect the public health and safety.

H.9.6 AMOUNT OF INDEMNIFICATION

The *Price-Anderson Act* establishes a system of private insurance and federal indemnification to ensure compensation for damage or injuries suffered by the public in a nuclear incident. The current amount of $10.26 billion reflects a threshold level beyond which Congress would review the need for additional payment of claims in the case of a nuclear incident with catastrophic damage. The limit for incidents that occur outside the United States is $500 million, and the nuclear material must be owned by, and used by or under contract with, the United States.

H.9.7 INDEMNIFICATION OF TRANSPORTATION ACTIVITIES

DOE indemnifies any nuclear incident that arises in the course of any transportation activities in connection with a DOE contractual activity, including transportation of nuclear materials to and from DOE facilities.

H.9.8 COVERED NUCLEAR WASTE ACTIVITIES

The indemnification specifically includes nuclear waste activities that DOE undertakes in relation to the storage, handling, transportation, treatment, disposal of, or research and development on spent nuclear fuel, high-level radioactive waste, or transuranic waste. It would cover liability for incidents that could occur while wastes were in transit from nuclear power plants, at a storage facility, or at Yucca Mountain. If a DOE contractor or other indemnified person was liable for the nuclear incident or a precautionary evacuation that resulted from its contractual activities, that person would be indemnified for that liability. While DOE tort liability would be determined under the *Federal Tort Claims Act* [28 U.S.C. 1346(b), 1402(b), 2401(b), and 2671 through 2680], the Department would use contractors to transport spent nuclear fuel and high-level radioactive waste and to construct and operate a repository. Moreover, if public liability arose out of activities that the Nuclear Waste Fund supported, the Fund would pay compensation up to the maximum amount of protection. The NWPA established the fund to support federal activities for the disposal of spent nuclear fuel and high-level radioactive waste.

H.9.9 INDEMNIFICATION FOR STATE, AMERICAN INDIAN, AND LOCAL GOVERNMENTS

State, American Indian tribes, and local governments are persons in the sense that they might be indemnified if they incur legal liability. The *Price-Anderson Act* defines a person as including "(1) any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, government agency other than [DOE or the Nuclear Regulatory] Commission, any state or any political subdivision of, or any political entity within a state, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and (2) any legal successor, representative, agent, or agency of the foregoing" (42 U.S.C. 2214). A state or a political subdivision of a state could be entitled to indemnification for legal liability, which would include all reasonable additional costs of responding to a nuclear incident or an authorized precautionary evacuation. In addition, indemnified persons could include contractors, subcontractors, suppliers, shippers, transporters, emergency response workers, health professional personnel, workers, and victims.

H.9.10 PROCEDURES FOR CLAIMS AND LITIGATION

Numerous provisions ensure the prompt availability and equitable distribution of compensation, which would include emergency assistance payments, consolidation and prioritization of claims in one federal court, channeling of liability to one source of funds, and waiver of certain defenses in the event of a large incident. The *Price-Anderson Act* authorizes payments for immediate assistance after a nuclear incident. In addition, it provides for the establishment of coordinated procedures for the prompt handling, investigation, and settlement of claims that result from a nuclear incident.

H.9.11 FEDERAL JURISDICTION OVER CLAIMS

The U.S. District Court for the district in which a nuclear incident occurred would have original jurisdiction "with respect to any [suit asserting] public liability...without regard to the citizenship of any party or the amount in controversy" [42 U.S.C. 2210(n)]. If a case was brought in another court, it would be removed to the U.S. District Court with jurisdiction upon motion of a defendant, NRC, or DOE.

H.9.12 CHANNELING LIABILITY TO ONE SOURCE OF FUNDS

The *Price-Anderson Act* channels the indemnification (that is, the payment of claims that arise from the legal liability of any person for a nuclear incident) to one source of funds. This economic channeling eliminates the need to sue all potential defendants or to allocate legal liability among multiple potential defendants. Economic channeling results from the broad definition of indemnified persons to include any person who could be legally liable for a nuclear incident. Therefore, regardless of individual legal liability for a nuclear incident that resulted from a DOE contractual activity or NRC-licensed activity, the indemnity would pay the claim.

In the hearings on the original Act, "the question of protecting the public was raised where some unusual incident, such as negligence in maintaining an airplane motor, should cause an airplane to crash into a reactor and thereby cause damage to the public. Under this bill, the public is protected and the airplane company can also take advantage of the indemnification and other proceedings" (DIRS 155789-DOE 1999, p. 12).

H.9.13 LEGAL LIABILITY UNDER STATE TORT LAW

The *Price-Anderson Act* does not define legal liability, but the legislative history clearly indicates that state tort law determines the covered legal liabilities (DIRS 155789-DOE 1999, p. A-6). In 1988, public liability action was defined to state explicitly that "the substantive rules for decision in such action shall be derived from the law of the state in which the nuclear incident involved occurs, unless such law is inconsistent with the provisions of [Section 2210 of Title 42]" (42 U.S.C. 2014).

H.9.14 PROVISIONS WHERE STATE TORT LAW MAY BE WAIVED

The *Price-Anderson Act* includes provisions to minimize protracted litigation and to eliminate the need to prove the fault of or to allocate legal liability among various potential defendants. Certain provisions of state law may be superseded by uniform rules that the Act prescribes, such as a limitation on punitive damages. In the case of an extraordinary nuclear occurrence, the Act imposes strict liability by requiring the waiver of any defenses in relation to conduct of the claimant or fault of any indemnified person. Such waivers would result, in effect, in strict liability, the elimination of charitable and governmental immunities, and the substitution of a 3-year discovery rule in place of statutes of limitations that would normally bar all suits after a specified number of years.

H.9.15 COVERAGE AVAILABLE FOR INCIDENTS IF THE PRICE-ANDERSON ACT DOES NOT APPLY

If an incident does not involve the actual release of radioactive materials or a precautionary evacuation is not authorized, *Price-Anderson Act* indemnification does not apply. If the indemnification does not apply, liability is determined under state law, as it would be for any other type of transportation incident. Private insurance could apply. As noted above, however, the Act would cover all DOE contracts for transportation of spent nuclear fuel and high-level radioactive waste to a repository for nuclear incidents and precautionary evacuations. Indemnified persons under that DOE contractual activity would include the contractors, subcontractors, suppliers, state, American Indian tribes, local governments, shippers and transporters, emergency response workers, and all other workers and victims.

Carriers would have private insurance to cover liability from a nonnuclear incident and for environmental restoration for such incidents. The *Motor Carrier Act* (42 U.S.C. 10927) and its implementing regulations (49 CFR Part 387) require all motor vehicles that carry spent nuclear fuel or high-level radioactive waste to maintain financial responsibility of at least $5 million. Federal law does not require rail, barge, or air carriers of radioactive materials to maintain liability coverage, but these carriers often voluntarily cover such insurance. Private insurance policies often exclude coverage of nuclear incidents. Therefore, private insurance policies generally apply only to the extent that the *Price-Anderson Act* is not applicable.

H.10 National Academy of Sciences Findings and Recommendations

In 2006, the National Academy of Sciences Committee on Transportation of Radioactive Waste issued *Going the Distance? The Safe Transport of Spent Nuclear and High-Level Radioactive Waste in the United States* (DIRS 182032-National Research Council 2006, all). The following sections quote from the National Academy of Sciences findings and recommendations that are relevant to this Repository SEIS, followed by a discussion of the DOE position on or approach to the respective findings and recommendations.

H.10.1 TRANSPORTATION SAFETY AND SECURITY

Principal Academy Finding on Transportation Safety

> "The committee could identify no fundamental technical barriers to the safe transport of spent nuclear fuel and high-level radioactive waste in the United States. Transport by highway (for small-quantity shipments) and by rail (for large-quantity shipments) is, from a technical viewpoint, a low-radiological-risk activity with manageable safety, health, and environmental consequences when conducted with strict adherence to existing regulations. However, there are a number of social and institutional challenges to the successful initial implementation of large-quantity shipping programs that will require expeditious resolution as described in this report. Moreover, the challenges of sustained implementation should not be underestimated."

DOE agrees that the transportation of spent nuclear fuel and high-level radioactive waste has a low radiological risk with manageable safety. DOE also agrees that there are social and institutional challenges, but the Department believes it would meet these challenges successfully through a process that has transportation safety as a priority.

Principal Academy Finding on Transportation Security

> "Malevolent acts against spent fuel and high-level waste shipments are a major technical and societal concern, especially following the September 11, 2001, terrorist attacks on the United States. The committee judges that some of its recommendations for improving transportation safety might also enhance transportation security. The Nuclear Regulatory Commission is undertaking a series of security studies, but the committee was unable to perform an in-depth technical examination of transportation security because of information constraints."

Academy Recommendation

> "An independent examination of the security of spent fuel and high-level waste transportation should be carried out prior to the commencement of large-quantity shipments to a federal repository or to interim storage. This examination should provide an integrated evaluation of the threat environment, the response of packages to credible malevolent acts, and operational security requirements for protecting spent fuel and high-level waste while in transport. This examination should be carried out by a technically knowledgeable group that is independent of the government and free from institutional and financial conflicts of interest. This group should be given full access to the necessary classified documents and Safeguards Information to carry out this task. The findings and

> recommendations from this examination should be made available to the public to the fullest extent possible."

Transportation safeguards and security are among DOE's highest priorities as it plans for shipments of spent nuclear fuel and high-level radioactive waste to the proposed repository. In this Repository SEIS, DOE has evaluated the consequences of potential acts of sabotage or terrorism during the transport of spent nuclear fuel and high-level radioactive waste. The Department would build the security program for the repository shipments on the security program that it has developed and successfully used in past decades for shipments of spent nuclear fuel to DOE facilities from foreign and domestic reactors.

An effective security program must protect members of the public near transportation routes as well as potential threats to workers, and it must include security elements appropriate to each phase of transportation. Continual testing of security procedures would result in improvements in the security system through completion of transportation operations for Yucca Mountain. The most important elements of a secure transportation program include physical security systems, information security, materials control and accounting, personnel security, security program management, and emergency response capabilities.

DOE is working closely with other federal agencies including the NRC, Department of Homeland Security, and the Transportation Security Agency to understand and eliminate potential threats to repository shipments. In addition to its domestic efforts, the Department is a member of the International Working Group on Sabotage for Transport and Storage Casks, which is investigating the consequences of a potential act of sabotage and exploring opportunities to enhance the physical protection of casks. As a result of these efforts, DOE would modify its methods and systems as appropriate between now and the time of shipments.

In coordination with other federal agencies, DOE is working with stakeholders including state, tribal, and local governments; industry associations such as the Association of American Railroads; and technical advisory and oversight organizations such as the National Academy of Sciences and the Nuclear Waste Technical Review Board. This allows DOE to take advantage of the experience and practical recommendations of experts on a broad range of security-related technical, procedural, and operational matters.

H.10.2 TRANSPORTATION RISK

Academy Finding

> "There are two types of transportation risk: health and safety risks and social risks. The health and safety risks arise from the potential exposure of transportation workers as well as other people who travel, work, or live near transportation routes to radiation that may be emitted or released from these loaded packages. Social risks arise from social processes and human perceptions and can have both direct socioeconomic impacts and perception-based impacts.
>
> There are two potential sources of radiological exposures from transporting spent fuel and high-level waste: (1) radiation shine from spent fuel and high-level waste transport packages under normal transport conditions; and (2) potential increases in radiation shine and release of radioactive materials from transport packages under accident conditions

> that are severe enough to compromise fuel element and package integrity. The radiological risks associated with the transportation of spent fuel and high-level waste are well understood and are generally low, with the possible exception of risks from releases in extreme accidents involving very long duration, fully engulfing fires. While the likelihood of such extreme accidents appears to be very small, their occurrence cannot be ruled out based on historical accident data for other types of hazardous material shipments. However, the likelihood of occurrence and consequences can be reduced further through relatively simple operational controls and restrictions and route-specific analyses to identify and mitigate hazards that could lead to such accidents."

Academy Recommendation

> "To address radiological risk, the NAS stated there were clear transportation operations and safety advantages to be gained from shipping older (i.e. radiologically and thermally cooler) spent fuel first.
>
> Transportation planners and managers should undertake detailed surveys of transportation routes to identify potential hazards that could lead to or exacerbate extreme accidents involving very long duration, fully engulfing fires. Planners and managers should also take steps to avoid or mitigate such hazards before the commencement of shipments or shipping campaigns."

This Repository SEIS evaluates the radiological risks of transportation accidents (in Chapter 6 and Appendix G) and finds these risks to be very low, as did the Yucca Mountain FEIS. In addition, NRC has evaluated the response of spent nuclear fuel casks to the environments that existed during the Baltimore tunnel fire and the Caldecott tunnel fire, which would be representative of long-duration, fully engulfing fires. These evaluations (Appendix G, Section G.9.4) show that releases of radioactive material during these types of events, if they occurred at all, would be very small. Based on recommendations from the NRC, the Association of American Railroads has modified its operating standards to prohibit trains that carry flammable materials from being in a tunnel at the same time as a train that carries spent nuclear fuel. This administrative adjustment addresses some of the concerns of the Academy.

An initial step in the DOE planning process to ship spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain Repository would be to identify a national suite of routes, both rail and highway, that DOE could use. DOE is working with stakeholder groups in the process of examining potential routing criteria in the route identification process. State Regional Group committees, tribal governments, transportation associations, industry, federal agencies, and local government organizations are some of the groups that work collaboratively with DOE in this process.

Academy Finding

> "The social risks for spent fuel and high-level waste transportation pose important challenges to the successful implementation of programs for transporting spent fuel and high-level waste in the United States. Such risks have received substantially less attention than health and safety risks, and some are difficult to characterize. Current research and practice suggest that transportation planners and managers can take early proactive steps to characterize, communicate, and manage the social risks that arise from their operations. Such steps may have additional benefits: they may increase the openness and transparency of transportation planning and programs; build community

> capacity to mitigate these risks; and possibly increase trust and confidence in transportation programs."

Academy Recommendation

> "Transportation implementers should take early and proactive steps to establish formal mechanisms for gathering high-quality and diverse advice about social risks and their management on an ongoing basis. The committee makes two recommendations for the establishment of such mechanisms for the Department of Energy's program to transport spent fuel and high-level waste to a federal repository at Yucca Mountain: (1) expand the membership and scope of an existing advisory group (Transportation External Coordination Working Group; see Chapter 5) to obtain outside advice on social risk, including impacts and management; and (2) establish a transportation risk advisory group that is explicitly designed to provide advice on characterizing, communicating, and mitigating the social, security, and health and safety risks that arise from the transportation of spent fuel and high-level waste to a federal repository or interim storage. This group should be comprised of risk experts and practitioners drawn from the relevant technical and social science disciplines and should be convened under the Federal Advisory Committee Act or a similar arrangement to enhance the openness of its operations. Its members should receive security clearances to facilitate access to appropriate transportation security information. The existing federal Nuclear Waste Technical Review Board, which will cease operations no later than one year after the Department of Energy begins disposal of spent fuel or high-level waste in a repository, could be broadened to serve this function."

DOE recognizes the importance of open and effective public communication for a successful transportation program. DOE has proposed reviving the Communications Topic Group within the Transportation External Coordination Working Group to address how the Department can improve its communication methods on transportation of spent nuclear fuel and high-level radioactive waste to effectively manage perception of risk. DOE would proceed based on input from the Transportation External Coordination Working Group membership.

H.10.3 CURRENT CONCERNS ABOUT TRANSPORTATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

H.10.3.1 Package Performance

Academy Finding

> "Transportation packages play a crucial role in the safety of spent fuel and high-level radioactive waste shipments by providing a robust barrier to the release of radiation and radioactive material under both normal transport and accident conditions. International Atomic Energy Agency package performance standards and associated Nuclear Regulatory Commission regulations are adequate to ensure package containment effectiveness over a wide range of transport conditions, including most credible accident conditions. However, recently published work suggests that extreme accident scenarios involving very long duration, fully engulfing fires might produce thermal loading conditions sufficient to compromise containment effectiveness. The consequences of such thermal loading conditions for containment effectiveness are the subject of ongoing

> investigations by the Nuclear Regulatory Commission and other parties, and this work is improving the understanding of package performance. Nonetheless, additional analyses and experimentation are needed to demonstrate a bounding-level understanding of package performance in response to very long duration, fully engulfing fires for a representative set of package designs."

Academy Recommendation

> "The Nuclear Regulatory Commission should build on recent progress in understanding package performance in very long duration fires. To this end, the agency should undertake additional analyses of very long duration fire scenarios that bound expected real world accident conditions for a representative set of package designs that are likely to be used in future large-quantity shipping programs. The objectives of these analyses should be to:
>
> - Understand the performance of package barriers (spent fuel cladding and package seals);
>
> - Estimate the potential quantities and consequences of any releases of radioactive material; and
>
> - Examine the need for regulatory changes (e.g., package testing requirements) or operational changes (e.g., restrictions on trains carrying spent fuel) either to help prevent accidents that could lead to such fire conditions or to mitigate their consequences.
>
> Strong consideration should also be given to performing well-instrumented tests for improving and validating the computer models used for carrying out these analyses, perhaps as part of the full-scale test planned by the Nuclear Regulatory Commission for its package performance study. Based on the results of these investigations, the Commission should implement operational controls and restrictions on spent fuel and high-level radioactive waste shipments as necessary to reduce the chances that such fire conditions might be encountered in service. Such effective steps might include, for example, additional operational restrictions on trains carrying spent fuel and high-level radioactive waste to prevent co-location with trains carrying flammable materials in tunnels, in rail yards, and on sidings."

As Section H.10.2 notes, NRC has addressed operating restrictions for tunnels by working with the Association of American Railroads to adjust rail operating practices. In addition, DOE has committed to supporting the NRC Package Performance Study to better understand severe accidents.

Academy Finding

> "The committee strongly endorses the use of full-scale testing to determine how packages will perform under both regulatory and credible extra-regulatory conditions. Package testing in the United States and many other countries is carried out using good engineering practices that combine state-of-the-art structural analyses and physical tests to demonstrate containment effectiveness. Full-scale testing is a very effective tool both for guiding and validating analytical engineering models of package performance and for

> demonstrating the compliance of package designs with performance requirements. However, deliberate full-scale testing of packages to destruction through the application of forces that substantially exceed credible accident conditions would be marginally informative and is not justified given the considerable costs for package acquisitions that such testing would require."

Academy Recommendation

> "Full-scale package testing should continue to be used as part of integrated analytical, computer simulation, scale-model, and testing programs to validate package performance. Deliberate full-scale testing of packages to destruction should not be required as part of this integrated analysis or for compliance demonstrations."

DOE would use NRC-certified casks for transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository. Cask vendors would supply these NRC-certified casks to DOE under contractual requirements. To obtain the certificate, the vendors would conduct such testing as the NRC required.

H.10.3.2 Route Selection for Research Reactor Spent Fuel Transport

Academy Finding

> "The Department of Energy's procedures for selecting routes within the United States for shipments of foreign research reactor spent fuel appear on the whole to be adequate and reasonable. These procedures are risk informed; they make use of standard risk assessment methodologies in identifying a suite of potential routes and then make final route selections by taking into account security, state and tribal preferences, and information from states and tribes on local transport conditions. The Department of Energy's procedures reflect the agency's position (which is consistent with Department of Transportation regulations) that the states are competent and responsible for selecting highway routes. For rail route selection, the Department of Energy's practice of negotiating routes with carriers in consultation with states is analogous to its interaction with states on highway routing."

Academy Recommendation

> "The Department of Energy should continue to ensure the systematic, effective involvement of states and tribal governments in its decisions involving routing and scheduling of foreign and DOE research reactor spent fuel shipments."

For shipments to the repository, DOE would use its *Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain: A Guide to Stakeholder Interactions* (DIRS 172433-DOE 2003, all) to guide interactions with state and tribal governments. During planning and actual transportation operations, DOE would involve these stakeholders in route identification, funding approaches for emergency response planning and training, understanding safeguards and security requirements, operational practices, and communications and information access.

DOE is working collaboratively with states through State Regional Group committees (whose members are state officials responsible for transportation policy, law enforcement, emergency response, and oversight of hazardous materials shipments) and with American Indian tribal governments to assist them to prepare for the shipments.

In addition to State Regional Group and tribal coordination, a national cooperative effort is underway as part of the Transportation External Coordination Working Group and its various Topic Groups, which involves a broad range of stakeholder organizations that routinely interact with DOE to provide input and recommendations on transportation planning and program information. States, tribes, and industry are working with DOE to guide and focus emergency training, coordination with local officials, and other transportation activities to prepare for shipments to the repository.

Academy Finding

> "Highway routes for shipment of spent nuclear fuel are dictated by DOT regulations (49 CFR Part 397). The regulations specify that shipments normally must travel by the fastest route using highways designated by the states or the federal government. They do not require the carrier or shipper to evaluate risks of portions of routes that meet this criterion. These regulations are a satisfactory means of ensuring safe transportation, provided that the shipper actively and systematically consults with the states and tribes along potential routes and that states follow the route designation procedures prescribed by the DOT."

Academy Recommendation

> "DOT should ensure that states that designate routes for shipment of spent nuclear fuel rigorously comply with its regulatory requirement that such designations be supported by sound risk assessments. DOT and DOE should ensure that all potentially affected states are aware of and prepared to fulfill their responsibilities regarding highway route designations."

DOE is working collaboratively with states through State Regional Group committees (whose members are state officials responsible for transportation policy, law enforcement, emergency response, and oversight of hazardous materials shipments) and with American Indian tribal governments to assist them to prepare for the shipments.

As part of the routing discussions, DOE has provided training to officials of these stakeholders on its routing model (TRAGIS; DIRS 181276-Johnson and Michelhaugh 2003, all) and the risk model (RADTRAN 5; DIRS 150898-Neuhauser and Kanipe 2000, all). If states or tribes choose to designate alternative highway routes, technical assistance is available from the experts at the national laboratories who manage these two models. In addition, State Regional Group staff support their states with routing assistance as part of the cooperative efforts DOE supports.

H.10.4 FUTURE CONCERNS FOR TRANSPORTATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

H.10.4.1 Mode for Transporting Spent Nuclear Fuel and High-Level Radioactive Waste to a Federal Repository

Academy Finding

> "Transport of spent fuel and high-level waste by rail has clear safety, operational, and policy advantages over highway transport for large-quantity shipping programs. The

committee strongly endorses DOE's selection of the "mostly rail" option for the Yucca Mountain transportation program for the following reasons:

- It reduces the total number of shipments to the federal repository by roughly a factor of five, which reduces the potential for routine radiological exposures, conventional traffic accidents, and severe accidents.
- Rail shipments have a greater physical separation from other vehicular traffic and reduced interactions with people along transportation routes, which also contributes to safety.
- Operational logistics are simpler and more efficient.
- There is a clear public preference for this option.

The committee does not endorse the development of an extended truck transportation program to ship spent fuel cross-country or within Nevada should DOE fail to complete construction of the Nevada rail spur or procure the necessary rail equipment by the time the federal repository is opened."

Academy Recommendation

"DOE should fully implement its mostly rail decision by completing construction of the Nevada rail spur, obtaining the needed rail packages and conveyances, and working with commercial spent fuel owners to ensure that facilities are available at plants to support this option. These steps should be completed before DOE commences the large-quantity shipment of spent fuel and high-level waste to a federal repository to avoid the need to procure infrastructure and construct facilities to support an extended truck transportation program. DOE should also examine the feasibility of further reducing its needs for cross-country truck shipments of spent fuel through the expanded use of intermodal transportation (i.e., combining heavy-haul truck, legal-weight truck, and barge) to allow the shipment of rail packages from plants that do not have direct rail access."

In this Repository SEIS, DOE analyzed the intermodal transfer of rail casks for generator sites that do not have direct rail access. The SEIS analysis identified nine such sites from which DOE would ship spent nuclear fuel or high-level radioactive waste using 2,650 truck shipments. In addition, DOE's transportation operational planning recognizes the value of barge and some heavy-haul truck shipments to maximize rail use to ship to the repository. DOE would address all modes of transportation in future transportation campaign plans.

H.10.4.2 Route Selection for Transportation to a Federal Repository

Academy Finding

"DOE has not made public a specific plan for selecting rail and highway routes for transporting spent fuel and high-level waste to a federal repository. DOE also has not determined the role of its program management contractors in selecting routes or specific plans for collaborating with affected states, tribes, and other parties."

Academy Recommendation

> "DOE should identify and make public its suite of preferred highway and rail routes for transporting spent fuel and high-level waste to a federal repository as soon as practicable to support state, tribal, and local planning, especially for emergency responder preparedness. DOE should follow the practices of its foreign research reactor spent fuel transport program of involving states and tribes in these route selections to obtain access to their familiarity with accident rates, traffic and road conditions, and emergency responder preparedness within their jurisdictions. Involvement by states and tribes may improve the public acceptability of route selections and may reduce conflicts that can lead to program delays."

An initial step in the DOE planning process to ship spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain Repository would be to identify a national suite of routes, both rail and highway, that DOE could use. DOE is working with stakeholder groups in the process of examining potential routing criteria in the route identification process. State Regional Group committees, tribal governments, transportation associations, industry, federal agencies, and local government organizations are some of the groups that work collaboratively with DOE in this process. DOE is performing and would continue to perform the work through a Topic Group of the Transportation External Coordination Working Group, and DOE intends to seek broader public input and collect comments on routing criteria and the process for development of a suite of routes. The process includes consideration of relevant regulations, industry practices, DOE requirements, and analysis of regional routes that states have previously evaluated in the process to identify a preliminary set of routes. DOE considers public involvement to be an essential element of a safe, efficient, and flexible transportation system.

H.10.4.3 Use of Dedicated Trains for Transport to a Federal Repository

Academy Finding

> "Studies carried out to date on transporting spent fuel by dedicated versus general trains have failed to show a clear radiological risk based advantage for either option. However, the committee finds that there are clear operational, safety, security, communications, planning, programmatic, and public preference advantages that favor dedicated trains. The committee strongly endorses DOE's decision to transport spent fuel and most high-level waste to a federal repository using dedicated trains."

Academy Recommendation

> "DOE should fully implement its dedicated train decision before commencing the large-quantity shipment of spent fuel and high-level waste to a federal repository to avoid the need for a stop gap shipping program using general trains."

DOE made a decision to use dedicated trains for its usual mode of shipment, which offers benefits that include efficient use of casks and railcars, lower dwell time in railyards and, in combination with other service features, direct service from origin to destination. DOE agrees with the Academy's recommendation.

H.10.4.4 Acceptance Order for Commercial Spent Nuclear Fuel Transport to a Federal Repository

Academy Finding

> "The order for accepting commercial spent fuel that is mandated by the Nuclear Waste Policy Act (NWPA) was not designed with the transportation program in mind. In fact, the acceptance order prescribed by the NWPA could require DOE to initiate its transportation program with long cross-country movements of younger (i.e., radiologically and thermally hotter) spent fuel from multiple commercial sites. There are clear transportation operations and safety advantages to be gained from shipping older (i.e., radiologically and thermally cooler) spent fuel first and for initiating the transportation program with relatively short, logistically simple movements to gain experience and build operator and public confidence."

Academy Recommendation

> "DOE should negotiate with commercial spent fuel owners to ship older fuel first to a federal repository or federal interim storage, except in cases (if any) where spent fuel storage risks at specific plants dictate the need for more immediate shipments of younger fuel. Should these negotiations prove to be ineffective, Congress should consider legislative remedies. Within the context of its current contracts with commercial spent fuel owners, DOE should initiate transport through a pilot program involving relatively short, logistically simple movements of older fuel from closed reactors to demonstrate the ability to carry out its responsibilities in a safe and operationally effective manner. DOE should use the lessons learned from this pilot activity to initiate its full-scale transportation program from operating reactors."

The terms of the "Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste" (10 CFR Part 961) require DOE to assign priority to those generator sites whose fuel was discharged earliest. This is usually called the "Oldest Fuel First" priority. DOE must pick up fuel from sites that were designated by those generators as those with the oldest fuel regardless of the location. At sites that were designated by the generators who own the oldest spent nuclear fuel, DOE must pick up fuel the generators have selected and that has cooled for at least 5 years.

Regardless of which fuel DOE would ship first, it would conduct the shipments safely in NRC-certified casks for that type of fuel.

H.10.4.5 Emergency Response Planning and Training

Academy Finding

> "Emergency responder preparedness is an essential element of safe and effective programs for transporting spent fuel and high-level waste. Emergency responder preparedness has so far received limited attention from DOE, states, and tribes for the planned transportation program to the federal repository. DOE has the opportunity to be innovative in carrying out its responsibilities for emergency responder preparedness. Emergency responders are among the most trusted members of their communities. Well-trained responders can become important emissaries for DOE's transportation program in

> local communities and can enhance community preparedness to respond to other kinds of emergencies."

Academy Recommendation

> "DOE should begin immediately to execute its emergency responder preparedness responsibilities defined in Section 180(c) of the Nuclear Waste Policy Act. In carrying out these responsibilities, DOE should proceed to (1) establish a cadre of professionals from the emergency responder community who have training and comprehension of emergency response to spent fuel and high-level waste transportation accidents and incidents; (2) work with the Department of Homeland Security to provide consolidated "all-hazards" training materials and programs for first responders that build on the existing national emergency response platform; (3) include trained emergency responders on the escort teams that accompany spent fuel and high-level waste shipments; and (4) use emergency responder preparedness programs as an outreach mechanism to communicate broadly about plans and programs for transporting spent fuel and high-level waste to a federal repository with communities along planned shipping routes."

The NWPA requires DOE to provide technical assistance and funds to states for training for public safety officials of appropriate units of local government and American Indian tribes through whose jurisdictions the Department plans to transport spent nuclear fuel or high-level radioactive waste to a repository. Section 180(c) further provides that training must cover procedures for safe routine transportation of these materials as well as for emergency response situations. Section 180(c) encompasses all modes of transportation, and funding would come from the Nuclear Waste Fund. Once implemented, this program would provide funding and technical assistance to train firefighters, law enforcement officers, and other public safety officials in preparation for repository shipments through their jurisdictions.

To implement this requirement, in the 1990s DOE published four *Federal Register* notices to solicit public comment on its approach to implementing Section 180(c). DOE responded to the comments in subsequent notices through April 1998. In 2004, DOE determined that it was timely to update its proposed policy for implementing Section 180(c).

The revisitation of Section 180(c) implementation began with the formation of a Transportation External Coordination Working Group Topic Group in April 2004. DOE also worked with State Regional Group committees and the Tribal Topic Group of the Transportation External Coordination Working Group to solicit stakeholder input on the policy. Topic Group members wrote issue papers on specific Section 180(c) topics such as allowable activities, funding allocation method, timing and eligibility, and definitions. Based on consideration of these materials, DOE developed a revised proposed policy that it issued in a *Federal Register* notice on July 23, 2007 (72 FR 40139) to request additional comments from stakeholders and the public. DOE plans to conduct a pilot program to test implementation of the Section 180(c) grant program prior to issuing the final Section 180(c) policy.

Pursuant to DOE's proposed policy, Section 180(c) funds would be intended for training specific to shipments of spent nuclear fuel and high-level radioactive waste to a repository. DOE would work with states and tribes to evaluate current preparedness for safe routine transportation and emergency response capability and would provide funding as appropriate to ensure that state, tribal, and local officials are prepared for such shipments. Section 180(c) funds would be intended to supplement but not duplicate existing training for safe routine transportation and emergency preparedness. DOE would work with states and tribes to coordinate and integrate Section 180(c) activities with existing training programs designed for state, tribal, and local public safety officials. Subject to the availability of appropriated funds, DOE anticipates making two types of grants available to eligible states and tribes. An initial assessment and planning grant would be available approximately 4 years prior to the commencement of shipments through a state or tribe's jurisdiction to support assessing the need for and planning for training. Subsequently, DOE intends to issue training grants in each of the 3 years prior to a scheduled shipment through a state or tribe's jurisdiction and every year that shipments are scheduled. Since state and tribal governments have primary responsibility to protect the public health and safety in their jurisdictions, they would have flexibility to decide for which allowable activities to request Section 180(c) assistance to meet their unique needs. States and tribes would be expected to coordinate with local public safety officials and to describe in their grant applications how they would use the grants to provide training to local public safety officials. The particular funding allocations would be determined in accordance with the approach in the proposed policy.

H.10.4.6 Information Sharing and Openness

Academy Finding

> "There is a conflict between the open sharing of information on spent fuel and high-level waste shipments and the security of transportation programs. This conflict is impeding effective risk communication and may reduce public acceptance and confidence. Post–September 11, 2001, efforts by transportation planners, managers, and regulators to further restrict information about spent fuel shipments make it difficult for the public to assess the safety and security of transportation operations."

Academy Recommendation

> "The Department of Energy, Department of Homeland Security, Department of Transportation, and Nuclear Regulatory Commission should promptly complete the job of developing, applying, and disclosing consistent, reasonable, and understandable criteria for protecting sensitive information about spent fuel and high-level waste transportation. They should also commit to the open sharing of information that does not require such protection and should facilitate timely access to such information: for example, by posting it on readily accessible Web sites."

Interactions with state and tribal governments would be guided by the *Office of Civilian Radioactive Waste Management Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain: A Guide to Stakeholder Interactions* (DIRS 172433-DOE 2003, all). During planning and actual transportation operations, states, tribes, industry, and other key stakeholders would be involved in route identification, funding approaches for emergency response planning and training, understanding safeguards and security requirements, operational practices, and communications and information access.

In addition to key stakeholder organizations and groups, the public has access to transportation information through the DOE Web site and through the Transportation External Coordination Working Group web page. These two mechanisms allow program information that should be shared reach a broad audience.

H.10.4.7 Organizational Structure of the Federal Transportation Program

Academy Finding

> "Successful execution of DOE's program to transport spent fuel and high-level waste to a federal repository will be difficult given the organizational structure in which it is embedded, despite the high quality of many current program staff. As currently structured, the program has limited flexibility over commercial spent fuel acceptance order [DIRS 182032-National Research Council 2006, Section 5.2.4]; it also has limited control over its budget and is subject to the annual federal appropriations process, both of which affect the program's ability to plan for, procure, and construct the needed transportation infrastructure. Moreover, the current program may have difficulty supporting what appears to be an expanding future mission to transport commercial spent nuclear fuel for interim storage or reprocessing. In the committee's judgment, changing the organizational structure of this program will improve its chances for success."

Academy Recommendation

> "The Secretary of Energy and the U.S. Congress should examine options for changing the organizational structure of the Department of Energy's program for transporting spent fuel and high-level waste to a federal repository. The following three alternative organizational structures, which are representative of progressively greater organizational change, should be specifically examined: (1) a quasi-independent DOE office reporting directly to upper-level DOE management; (2) a quasi-government corporation; or (3) a fully private organization operated by the commercial nuclear industry. The latter two options would require changes to the Nuclear Waste Policy Act. The primary objectives in modifying the structure should be to give the transportation program greater planning authority; greater budgetary flexibility to make the multiyear commitments necessary to plan for, procure, and construct the necessary transportation infrastructure; and greater flexibility to support an expanding future mission to transport spent fuel and high-level waste for interim storage or reprocessing. Whatever structure is selected, the organization should place a strong emphasis on operational safety and reliability and should be responsive to social concerns."

The NWPA defines the Federal Government's responsibilities for disposal of spent nuclear fuel and high-level radioactive waste. The NWPA created the Office of Civilian Radioactive Waste Management within DOE to carry out these responsibilities, which include the development of a transportation system. The Act requires the Office to maximize use of the private sector to implement its transportation responsibilities. That collaborative development effort is underway and would continue until the law changed.

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172433	DOE 2003	DOE (U.S. Department of Energy) 2003. *Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain: A Guide to Stakeholder Interactions*. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20041206.0113.
156703	DOT 1998	DOT (U.S. Department of Transportation) 1998. *Safety Compliance Oversight Plan for Rail Transportation of High-Level Radioactive Waste and Spent Nuclear Fuel, Ensuring the Safe, Routine Rail Transportation of Foreign Research Reactor Spent Nuclear Fuel.* Washington, D.C.: U.S. Department of Transportation, Federal Railroad Administration. ACC: MOL.20011212.0115.
175728	DOT 2004	DOT (U.S. Department of Transportation) 2004. *2004 Emergency Response Guidebook.* Washington, D.C.: U.S. Department of Transportation. ACC: MOL.20051020.0131.
182833	Golan 2005	Golan, P. 2005. "Letter Informing Stakeholders of Policy Adopted by the Department to Use Dedicated Trains for its Shipment of Spent Nuclear Fuel and High-Level Radioactive Waste to the Yucca Mountain Repository." Letter from P. Golan to Stakeholder, July 18, 2005, with attachment. ACC: HQO.20051003.0001.
181276	Johnson and Michelhaugh 2003	Johnson, P.E. and Michelhaugh, R.D. 2003. *Transportation Routing Analysis Geographic Information System (TRAGIS) User's Manual.* ORNL/NTRC-006, Rev. 0. Oak Ridge, Tennessee: Oak Ridge National Laboratory. ACC: MOL.20070712.0024.
182032	National Research Council 2006	National Research Council. 2006. *Going the Distance? The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States*. Washington, D.C.: National Academies Press. TIC: 259563.
150898	Neuhauser and Kanipe 2000	Neuhauser, K.S. and Kanipe, F.L. 2000. *RADTRAN 5, User Guide.* SAND2000-1257. Albuquerque, New Mexico: Sandia National Laboratories. TIC: 249356.

182897	Reyes 2005	Reyes, L.A. 2005. "Details and Projected Cost of a Demonstration Test of a Full-Scale Spent Nuclear Fuel Rail Transportation Cask Under the Package Performance Study." Policy Issue Notation from L.A. Reyes to the Commissioners, without attachments. ACC: MOL.20070913.0509.
152476	Sprung et al. 2000	Sprung, J.L.; Ammerman, D.J.; Breivik, N.L.; Dukart, R.J.; Kanipe, F.L.; Koski, J.A.; Mills, G.S.; Neuhauser, K.S.; Radloff, H.D.; Weiner, R.F.; and Yoshimura, H.R. 2000. *Reexamination of Spent Fuel Shipment Risk Estimates*. NUREG/CR-6672. Two volumes. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.20001010.0217.
182896	Vietti-Cook 2005	Vietti-Cook, A.L. 2005. "Details and Projected Cost of a Demonstration Test of a Full-Scale Spent Nuclear Fuel Rail Transportation Cask Under the Package Performance Study." Letter from A.L. Vietti-Cook (NRC) to Distribution, June 9, 2005, SECY-05-051, with attachments. ACC: MOL.20070913.0508.

Appendix I

Federal Register Notices

APPENDIX I. FEDERAL REGISTER NOTICES

The following table lists *Federal Register* notices used in this *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* (DOE/EIS-0250F-S1). Notices can be found on the U.S. Government Printing Office GPO Access website at http://origin.www.gpoaccess.gov/fr/.

Volume and page	Publication date	Title
44 FR 38690	July 2, 1979	"Transportation of Radioactive Materials; Memorandum of Understanding."
54 FR 63187	February 9, 1989	"Notice of Floodplain/Wetlands Involvement."
56 FR 49765	October 1, 1991	"Floodplain Statement of Findings for Surface-Based Investigations at Yucca Mountain, Nevada."
57 FR 48363	October 23, 1992	"Floodplain Statement of Findings for Site Characterization Activities at Yucca Mountain, NV."
60 FR 28680	June 1, 1995	"Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs."
64 FR 31554	June 11, 1999	"Floodplain and Wetlands Involvement; Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada."
64 FR 71331	December 21, 1999	"Advanced Notification to Native American Tribes of Transportation of Certain Types Of Nuclear Waste."
66 FR 14194	March 9, 2001	"Notice of Realty Action: Public Law 106-113, as Amended, Non-Competitive Sale of Public Lands and the Conveyance of Public Lands for Recreation and Public Purposes."
67 FR 39737	June 10, 2002	"Nye County Habitat Conservation Plan for Lands Conveyed at Lathrop Wells, NV."
67 FR 53359	August 15, 2002	"Public Land Order No. 7534; Extension of Public Land Order No. 6802; Nevada."
67 FR 63167	October 10, 2002	"In the Matter of All Power Reactor Licensees, Research and Test Reactor Licensees, and Special Nuclear Material Licensees Who Possess and Ship Spent Nuclear Fuel; Order Modifying License. (Effective Immediately)"
67 FR 65539	October 25, 2002	"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, NV."
67 FR 65564	October 25, 2002	"Environmental Impact Statements; Notice of Availability."

Volume and page	Publication date	Title
67 FR 79906	December 31, 2002	"Record of Decision for the Final Environmental Impact Statement for the Relocation of Technical Area 18 Capabilities and Materials at the Los Alamos National Laboratory."
68 FR 58815	October 10, 2003	"Electronic Maintenance and Submission of Information; Final Rule. (Part 63—Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada.)"
68 FR 74951	December 29, 2003	"Notice of Preferred Nevada Rail Corridor."
68 FR 74965	December 29, 2003	"Notice of Proposed Withdrawal and Opportunity for Public Meeting; Nevada."
69 FR 2280	January 14, 2004	"Changes to Adjudicatory Process 10 CFR Parts 1, 2, 50, 51, 52, 54, 60, 63, 70, 72, 73, 75, 76, and 110. (Part 63-- Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada.)"
69 FR 3698	January 26, 2004	"Compatibility With IAEA Transportation Safety Standards (TS–R–1) and Other Transportation Safety Amendments."
69 FR 18557	April 8, 2004	Record of Decision on Mode of Transportation and Nevada Rail Corridor for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV."
69 FR 18565	April 8, 2004	"Notice of Intent to Prepare an Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV."
69 FR 22496	April 26, 2004	"Comment Period Extension and Additional Public Scoping Meetings for an Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV."
69 FR 52040 – 52048	August 24, 2004	"Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions."
69 FR 58841	October 1, 2004	"Hazardous Materials Regulations; Compatibility With the Regulations of the International Atomic Energy Agency; Correction; Final Rule."
70 FR 35073	June 16, 2005	"West Valley Demonstration Project Waste Management Activities."
70 FR 49014	August 22, 2005	"Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada; Proposed Rule."
70 FR 53313	September 8, 2005	"Implementation of a Dose Standard After 10,000 Years."

Volume and page	Publication date	Title
70 FR 56647	September 28, 2005	“Notice of Intent To Prepare a Programmatic Environmental Impact Statement, Amend Relevant Agency Land Use Plans, Conduct Public Scoping Meetings, and Notice of Floodplain and Wetlands Involvement.”
70 FR 75165	December 19, 2005	“Office of Environmental Management; Record of Decision for the Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement.”
70 FR 76854	December 28, 2005	“Public Land Order No. 7653; Withdrawal of Public Lands for the Department of Energy To Protect the Caliente Rail Corridor; Nevada.”
71 FR 10068	February 28, 2006	“Notice of Issuance of Materials License Snm–2513 for the Private Fuel Storage Facility.”
71 FR 38391	July 6, 2006	“Notice of Availability of the Draft Environmental Assessment for the Proposed Infrastructure Improvements for the Yucca Mountain Project, Nevada.”
71 FR 60484	October 13, 2006	“Amended Notice of Intent To Expand the Scope of the Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV.”
71 FR 60490	October 13, 2006	“Supplement to 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, NV.”
71 FR 61731	October 19, 2006	“Notice of Intent To Prepare a Supplement to the Stockpile Stewardship and Management Programmatic Environmental Impact Statement—Complex 2030.”
71 FR 65785	November 9, 2007	“Extension of Public Comment Period and Additional Public Meeting for the Supplemental Yucca Mountain Rail Corridor and Rail Alignment Environmental Impact Statement.”
71 FR 65786	November 9, 2006	“Extension of Public Comment Period and Additional Public Meeting for the Supplement to 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, NV.”
71 FR 76834	December 21, 2006	“Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shipments.”
71 FR 76852	December 21, 2006	“Rail Transportation Security.”
72 FR 331	January 4, 2007	“Notice of Intent To Prepare a Programmatic Environmental Impact Statement for the Global Nuclear Energy Partnership.”

Volume and page	Publication date	Title
72 FR 1235	January 10, 2007	"Notice of Proposed Withdrawal and Opportunity for Public Meeting; Nevada."
72 FR 14543	March 28, 2007	"Notice of Intent To Prepare a Supplemental Environmental Impact Statement for Surplus Plutonium Disposition at the Savannah River Site."
72 FR 31824	June 8, 2007	"EPA and Army Corps of Engineers Guidance Regarding Clean Water Act Jurisdiction after Rapanos."
72 FR 40135	July 23, 2007	"Notice of Intent To Prepare an Environmental Impact Statement for the Disposal of Greater-Than-Class-C Low-Level Radioactive Waste."
72 FR 40139	July 23, 2007	"Office of Civilian Radioactive Waste Management; Safe Routine Transportation and Emergency Response Training; Technical Assistance and Funding."
72 FR 58071	October 12, 2007	"Draft 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, NV and Draft 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."
72 FR 58081	October 21, 2007	"Environmental Impact Statements and Regulations; Availability of EPA Comments."
73 FR 16436	March 27, 2008	"National Ambient Air Quality Standards for Ozone."
73 FR 30908	May 29, 2008	"Notice of Intent To Prepare a Programmatic Environmental Impact Statement To Evaluate Solar Energy Development, Develop and Implement Agency-Specific Programs, Conduct Public Scoping Meetings, Amend Relevant Agency Land Use Plans, and Provide Notice of Proposed Planning Criteria"

Appendix J

Distribution List

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J. Distribution List

APPENDIX J

DISTRIBUTION LIST

The U.S. Department of Energy (DOE or the Department) is providing copies of this *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* (DOE/EIS-0250F-S1) to federal, state, and local elected and appointed officials and agencies of government; American Indian groups; and national, state, and local environmental and public interest groups.

This appendix presents the distribution list of the above groups. Although the list of other organizations and individuals is not included, DOE has distributed more than 4,000 copies of this Repository SEIS, and the Nevada Rail Corridor SEIS and Rail Alignment EIS. The Department will provide copies to other interested parties on request.

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Federal Maritime Commission
Bureau of Consumer Complaints & Licensing

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Paducah Gaseous Diffusion Plant

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Northern New Mexico Citizens' Advisory Board

Mr. Spencer Gross
Oak Ridge Site-Specific Advisory Board
SSAB Support Office

Mr. Ken Korkia
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Rocky Flats Citizens Advisory Board

Ms. Terri Lamb
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Ms. Menice Manzanares
CAB Administrator
Northern New Mexico Citizens' Advisory Board

Ms. Carla Sanda
SSAB Administrator
Community Advisory Board for Nevada Test
Site Programs
c/o Stroller Navarro Joint Venture

J.3 State of Nevada

J.3.1 STATEWIDE OFFICES AND LEGISLATURE

The Honorable Jim Gibbons
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The Honorable Mark E. Amodei
Senate President Pro Tempore
Nevada State Senate
Committee on High-Level Radioactive Waste

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Nevada State Assembly

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Southern Nevada Water Authority – Resources

The Honorable Jerry Claborn
Vice Chairman, Natural Resources, Agriculture and Mining
Nevada State Assembly

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Nevada State Clearinghouse

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Nevada State Senate
Committee on High-Level Radioactive Waste

The Honorable Dean A. Rhoads
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Nevada State Senate

The Honorable Alice Constandina (Dina) Titus
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Committee on High-Level Radioactive Waste

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J.3.2 STATE AND LOCAL AGENCIES AND OFFICIALS

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Mr. Mike Baughman
Intertech Services Corporation

The Honorable Kenneth Benson
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The Honorable Jim Bilyeu, Chair
Inyo County Board of Supervisors

Mr. Darin Bloyed
Chairman
Pershing County Board of Commissioners

The Honorable Nancy Boland, Chair
Esmeralda County Commission

The Honorable Susan Cash
Inyo County Board of Supervisors

The Honorable Robert A. Cashell, Sr.
Mayor
City of Reno

The Honorable Chuck Chapin, Vice Chair
Lander County Board of Commissioners
Nuclear Waste Liaison
Mr. Bob Cooper
Manager, Economic Development Dept.
City of Henderson

Mr. Ron Damele
Public Works Director
Eureka County Public Works

Mr. Bill Deist
County Administrator
Humboldt County

The Honorable Joni Eastley, Vice Chair
Nye County Board of Commissioners

The Honorable Clinton "Brent" Eldridge
Chair
White Pine County Commission

Mr. Bryan Elkins
Director, Community Development
City of Caliente

The Honorable Edward Fowler, Chair
Mineral County Board of Commissioners

Mr. Matt Gaffney, Project Coordinator
Yucca Mountain Repository Assessment Office
Inyo County

Mr. John Gervers
Latir Energy Consultants

Mr. Robert Hadfield
Interim Cty Manager
Lyon County

The Honorable Ronda Hammond-Hornbeck
Chair
Lincoln County Board of Commissioners

The Honorable Susan Holecheck
Mayor
City of Mesquite

The Honorable Gary Hollis, Chair
Nye County Board of Commissioners

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Mr. Aaron R. Kenneston
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Esmeralda County Repository Oversight
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The Honorable Monte Martin
Fernley City Council

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City of Caliente

The Honorable Wade Poulsen, Vice Chair
Board of Lincoln County Commissioners

The Honorable Rory Reid, Chair
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Mr. Ace Robison
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The Honorable Warren Russell
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City of Fallon

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Ms. Judy Treichel
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The Honorable Gwen Washburn, Chair
Churchill County Board of Commissioners

Mr. Pat Whitten
Director of Administration & Budgets
Story County Courthouse

Mr. Ron Williams
County Manager
Nye County

J.4 Other States and Territories

The Honorable Anibal Acevedo-Vila
Governor of Puerto Rico

The Honorable John E. Baldacci
Governor of Maine

The Honorable Mike Beebe
Governor of Arkansas

The Honorable Kathleen Babineaux Blanco
Governor of Louisiana

The Honorable Haley Barbour
Governor of Mississippi

The Honorable Rod R. Blagojevich
Governor of Illinois

The Honorable Matt Blunt
Governor of Missouri

The Honorable Phil Bredesen
Governor of Tennessee

The Honorable Donald L. Carcieri
Governor of Rhode Island

The Honorable Felix Camacho
Governor of Guam

The Honorable Jon S. Corzine
Governor of New Jersey

The Honorable Charlie Crist
Governor of Florida

The Honorable Chet Culver
Governor of Iowa

The Honorable Mitch Daniels
Governor of Indiana

The Honorable James H. Douglas
Governor of Vermont

The Honorable Jim Doyle
Governor of Wisconsin

The Honorable Ernie Fletcher
Governor of Kentucky

The Honorable Jennifer M. Granholm
Governor of Michigan

The Honorable Dave Heineman
Governor of Nebraska

The Honorable John Hoeven
Governor of North Dakota

The Honorable Michael F. Easley
Governor of North Carolina

The Honorable David D. Freudenthal
Governor of Wyoming

The Honorable Christine O. Gregoire
Governor of Washington

The Honorable Charles Bradford "Brad" Henry
Governor of Oklahoma

The Honorable Jon M. Huntsman, Jr.
Governor of Utah

The Honorable Ted Kulongoski
Governor of Oregon

The Honorable Timothy "Tim" M. Kaine
Governor of Virginia

The Honorable Linda Lingle
Governor of Hawaii

The Honorable John H. Lynch
Governor of New Hampshire

The Honorable Joe Manchin, III
Governor of West Virginia

The Honorable Ruth Ann Minner
Governor of Delaware

The Honorable Frank Murkowski
Governor of Alaska

The Honorable Janet Napolitano
Governor of Arizona

The Honorable Martin O'Malley
Governor of Maryland

The Honorable C. L. Butch Otter
Governor of Idaho

The Honorable Sarah H. Palin
Governor of Alaska

The Honorable David A. Paterson
Governor of New York

The Honorable Deval Patrick
Governor of Massachusetts

The Honorable Timothy Pawlenty
Governor of Minnesota

The Honorable Sonny Perdue
Governor of Georgia

The Honorable Rick Perry
Governor of Texas

The Honorable M. Jodi Rell
Governor of Connecticut

The Honorable Edward G. Rendell
Governor of Pennsylvania

The Honorable William "Bill" Richardson
Governor of New Mexico

The Honorable Robert "Bob" R. Riley
Governor of Alabama

The Honorable Bill Ritter, Jr.
Governor of Colorado

The Honorable Michael M. Rounds
Governor of South Dakota

The Honorable Mark Sanford
Governor of South Carolina

The Honorable Arnold Schwarzenegger
Governor of California

The Honorable Brian Schweitzer
Governor of Montana

The Honorable Kathleen Sebelius
Governor of Kansas

The Honorable Ted Strickland
Governor of Ohio

The Honorable Togiola Tulafono
Governor of American Samoa

J.5 Native American Tribes and Organizations

Mr. Kenny Anderson
Tribal Representative
Las Vegas Paiute Tribe

The Honorable Richard Arnold
Chairman
Pahrump Paiute Tribe

The Honorable John Azbil, Sr.
President
Round Valley Indian Tribal Council

Ms. Sandra Barela
Tribal Representative
Ely Shoshone Tribe

The Honorable John A. Barrett
Chairman
Citizens Band of Potawatomi (OK)

The Honorable Eleanor Baxter
Chairwoman
Omaha Tribe of Nebraska

The Honorable Homer Bear, Jr.
Chairman
Sac & Fox Tribal of the Mississippi in Iowa
The Honorable Audrey Bennett
President
Prairie Island Indian Community in the State of Minnesota

The Honorable Kristi Begay
Tribal Chair
Wells Indian Colony Band Council
The Honorable Leonard Beowman
Chairman
Bear River Band of the Rohnerville Rancheria, California

The Honorable Dennis Bill
Chairman
Yomba Shoshone Tribe

Dr. Bonnie Eberhardt Bobb
Tribal Representative
Yomba Shoshone Tribe

The Honorable Claudia Brundin
Chairwoman
Blue Lake Racheria Indian Tribe

The Honorable John Blackhawk
Chairman
Winnebago Tribe of Nebraska

The Honorable Diana Buckner
Chairwoman
Ely Shoshone Tribe

Ms. Ila Bullets
Tribal Representative
Kaibab Band of Southern Paiutes

The Honorable Fred Cantu
Chief
Saginaw-Chippewa Indian Tribe

The Honorable Delia Carlyle
Chairwoman
Ak Chin Indian Community Council

Mr. Jerry Charles
Tribal Representative
Ely Shoshone Tribe

Mr. Lee Chavez
Tribal Representative
Bishop Paiute Indian Tribe

Mr. David Conrad
Executive Director
National Tribal Environmental Council (NTEC)

Mr. Vince Conway
Tribal Chairman
Yerington Paiute Tribe

The Honorable Sherry Cordova
Chairwoman
Cocopah Tribe of Arizona

Ms. Betty L. Cornelius
Tribal Representative
Colorado River Indian Tribes

The Honorable Darrin Daboda
Chairman
Moapa Band of Paiute Indians

The Honorable Carl Dahlberg
Chairman
Fort Independence Indian Tribe

Ms. Darlene Dewey
Tribal Representative
Yomba Shoshone Tribe

Ms. Brenda Drye
Tribal Representative
Kaibab Band of Southern Paiutes

Ms. Barbara Durham
Tribal Representative
Timbisha Shoshone Tribe

The Honorable Daniel Eddy, Jr.
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Colorado River Indian Tribes

The Honorable Blaine Edmo
Chairman, Business Council
Shoshone-Bannock Tribes of the Fort Hall
Reservation of Idaho

Mr. Atef Elzeftawy
Tribal Representative
Las Vegas Paiute Tribe

Mr. Ron Escobar
Tribal Representative
Chemehuevi Tribe

Ms. Pauline Esteves
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Timbisha Shoshone Tribe

The Honorable John Feliz, Jr.
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The Honorable Darrell Flyingman
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Cheyenne-Arapaho Tribes of Oklahoma

Mr. Maurice Frank-Churchill
Tribal Representative
Duckwater Shoshone Tribe

The Honorable Harold Frank
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Forest County Potawatomi Community of Wisconsin

Ms. Grace Goad
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Timbisha Shoshone Tribe

The Honorable Elizabeth Hansen
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Redwood Valley Rancheria of Pomo Indians of California

The Honorable Lori Harrison
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Las Vegas Indian Center

Mr. Bill Helmer
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The Honorable Mike Jackson, Sr.
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Quechan Tribe of the Fort Yuma Indian Reservation, California & Arizona

Mr. John A. James
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Cabazon Band of Mission Indians

Ms. Clara Belle Jim
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The Honorable Roland E. Johnson
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Pueblo of Laguna, New Mexico

The Honorable Jason Johnson
Governor
Pueblo of Acoma, New Mexico

Mr. Mel Joseph
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Mr. Gerald Kane
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Bishop Paiute Indian Tribe

Mr. Darryl King
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Chemehuevi Tribe

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National Congress of American Indians

The Honorable Joe Kennedy
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Timbisha Shoshone Tribe

Ms. Lawanda Laffoon
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Mr. Bill R. Larson
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Mr. Bill Larson
Western Shoshone Defense Project

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The Honorable George R. Lewis
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The Honorable Nora McDowell
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Fort Mojave Indian Tribe of Arizona, California & Nevada

The Honorable Arlan D. Melendez
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Reno-Sparks Indian Tribe

Mr. Calvin Meyers
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Moapa Band of Paiutes

The Honorable Dean Mike
Chairman
Twenty-Nine Palms Band of Mission Indians of California

The Honorable Richard M. Milanovich
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Agua Caliente Band of Cahuilla Indians

Ms. Lalovi Miller
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Moapa Band of Paiutes

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Confederated Tribes of the Umatilla Reservation, Oregon

Mr. Armand Minthorn
Confederated Tribes of the Umatilla Indian Reservation

The Honorable Alfreda L. Mitre
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Las Vegas Paiute Tribe

The Honorable Virgil Moose
Chairman
Big Pine Paiute Tribe of the Owens Valley

Ms. Gaylene Moose
Tribal Representative
Bishop Paiute Tribe

Mr. Wilfred Nabahe
Tribal Representative
Lone Pine Paiute-Shoshone Tribe

The Honorable Larry Nuckolls
Governor
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Mr. Willy Preacher
Tribal DOE Director
Shoshone-Bannock Tribe Fort Hall Business Council

The Honorable Kay Rhoads
Principal Chief
Sac & Fox Nation, Oklahoma

The Honorable William R. Rhodes
Governor
Gila River Indian Community of the Gila River Indian Reservation, Arizona

The Honorable Tony Salazar
Chairman
Kickapoo Tribe of Oklahoma

The Honorable Ruby Sam
Chairwoman
Duckwater Shoshone Tribe

The Honorable Joseph C. Saulque
Chairman
Benton Paiute Indian Tribe

Ms. Gevene E. Savala
Tribal Representative
Kaibab Band of Southern Paiutes

The Honorable George Scott
Town King
Thlopthlocco Tribal Town, Oklahoma

The Honorable Ona Segundo
Chairwoman
Kaibab Band of Southern Paiutes

The Honorable Arturo Senclair
Governor
Ysleta Del Sur Pueblo of Texas

The Honorable Joe Shirley, Jr.
President
Navajo Nation, Arizona, New Mexico & Utah

Mr. Herman Shorty
Navajo Nation

The Honorable Ivan L. Sidney
Chairman
Hopi Tribe of Arizona

The Honorable Barry E. Snyder, Sr.
President
Seneca Nation of New York

Mr. Philbert Swain
Moapa Band of Paiutes

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The Honorable Lee Watterson
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The Honorable Leona L. Williams
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Pinoleville Rancheria of Pomo Indians of California

The Honorable Charles Wood
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The Honorable Marjianne Yonge
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Ms. Jodi Dart
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Sierra Club

Ms. Janet Feldman
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Mr. John Flicker
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Progressive Leadership Alliance of Nevada

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Ms. Lisa Gover
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National Tribal Environmental Council (NTEC)

Ms. Nicole Graysmith
Legal Aid of North Carolina
Environmental Poverty Law Project

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Citizens for Alternatives to Radioactive
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Economists for Peace & Security at the Levy
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Committee to Bridge the Gap

Mr. Robert Holden
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National Congress of American Indians (NCAI)
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Mr. Toney Johnson
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Tri-Valley CAREs

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League of Women Voters

Mr. Lloyd Leonard
League of Women Voters

Mr. Pete Litster
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Mr. Alfred Meyer
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Mr. Ehrich Pica
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Mr. Gerald Pollet
Executive Director
Heart of America Northwest

Mr. Paul R. Portney
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Resources for the Future

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Senior Advisor
National Community Action Foundation

Ms. Laura Raicovich
Dia Art Foundation

Mr. Jim Riccio
Greenpeace International

Mr. Roger Rivera
President
National Hispanic Environmental Council

Nick Roth
Nuclear Age Peace Foundation

Mr. Thomas A. Schatz
President
Council for Citizens Against Government Waste

Mr. Paul Schwartz
National Campaign Director
Clean Water Action

Ms. Susan Shaer
Executive Director
Women's Action for New Directions

Ms. Kassie Siegel
Air Climate and Energy Director
Center for Biological Diversity

Ms. Alice Slater
President
Global Resource Action Center for the Environment

Ms. Gail Small
Executive Director
Native Action

Mr. Derek Stack
Executive Director
Great Lakes United

Mr. John Tanner
Coalition 21

Jennifer Olaranna Viereck
Healing Ourselves & Mother Earth

Mr. Mark Wenzler
Sierra Club
Legislative Office

Mr. Louis Zeller
Blue Ridge Environmental Defense League

J.7 Other Groups and Individuals

Mr. & Mrs. Dirk and Marta Agee
Commissioner
Tempiute Grazing Association

Mr. Ralph Anderson
Project Manager, Plant Support
Nuclear Energy Institute

Mr. Robert A. Apel
Newcrest Resources, Inc.

Ms. Anna Aurilio
Director, Washington, DC Office
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University of Nevada, Las Vegas
Harry Reid Center

A Mr. Tom Barry
Senior Policy Analyst & Co-founder
International Relations Center

Mr. Gerald W. Baughman
Nevada Eagle Resources, LLC

Mr. Robert A. Beck
Executive Vice President
National Coal Council

Arden L. Bement, Ph.D.
Director
National Science Foundation

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Admiral, Retired Frank L. "Skip" Bowman
President & Chief Executive Officer
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Nevada Mining Association

Mr. Richard Bryan, Chairman
Nevada Commission on Nuclear Projects

Mr. Dennis P. Bryan
Converse Consultants

Jackie Cabasso
Executive Director
Western States Legal Foundation

Mr. Paul J. Burkett
Nevada Gold & Casinos, Inc.

Ms. Anne deLain Clark
Coordinator
Radioactive Waste Consultation Task Force
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National Academy of Sciences

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National Association of Manufacturers

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American Petroleum Institute

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Association of American Railroads (AAR)
Safety & Operations Dept.

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Natural Resources Defense Council
Public Education

Ms. Arlene Grider
President
Independence Chamber of Commerce

Mr. David Hawkins
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Natural Resources Defense Council
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Mr. Walter Isaacson
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The Aspen Institute
Program on Energy, the Environment & the Economy

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Nuclear Information & Resource Service

Ms. Jill Kennay
Assistant Director
Natural Land Institute

Mr. Steven Kerekes
Director, Media Relations
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Outreach & Volunteer Dept.

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Western Interstate Energy Board (WIEB)

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Region III President
International Association of Emergency Managers
c/o General Physics Corporation

Mr. Paul Leventhal
Founding President
Nuclear Control Institute

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Edison Electric Institute

Mr. William Mackie
Program Manager
Western Governors' Association

Mr. Robert E. Marvin
Director
FRA/State Rail Safety Participation Program
c/o Transportation Division
Ohio Public Utilities Commission

Mr. Rod McCullum
Nuclear Energy Institute

Mr. David Mienke
Alliant Utilities, Inc.
Duane Arnold Energy Center

Mr. Brian J. O'Connell
Director, Nuclear Waste Program
National Assoc. of Regulatory Utility Commissioners (NARUC)

Ms. Mary Olson
Radioactive Waste Project & NIX MOX Campaign
Nuclear Information & Resource Service

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Brotherhood of Locomotive Engineers & Trainment

Mr. Duane Parde
Executive Director
American Legislative Exchange Council (ALEC)

Mr. William Ramsey
Executive Director
Troutman Sanders

Mr. Randy Rawson
President
American Boiler Manufacturers Association

Mr. Jim B. Reed
Transportation Program Director
National Conference of State Legislators
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Mr. Cort Richardson
Project Director
Council of State Governments - Eastern
Regional Conference (CSG/ERC)

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Center for Applied Research

Dr. Budhi Sagar
Technical Director
Southwest Research Institute
Center for Nuclear Waste Regulatory Analyses

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Nye Regional Medical Center

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CERM, Desert Research Institute
Center for Environmental Remediation &
Monitoring

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National Governors' Association

Ms. Linda Sikkema
Executive Director
National Conference of State Legislatures

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Harry Reid Center for Environmental Studies

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Washington TRU Solutions

Mr. Joe Strolin
Western Interstate Energy Board

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Mr. Robert Thompson
Energy Communities Alliance

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President
American Nuclear Society

Mr. Chris Turner
Training Coordinator
International Association of Fire Fighters (IAFF)
Hazardous Materials Training Department

Mr. George D. Turner
President & Chief Executive Officer
American Nuclear Insurers

Ms. Barbara Bauman Tyran
Director, Washington Relations
Electric Power Research Institute

Ms. Julie Ufner
Associate Legislative Director
National Association of Counties (NACo)

Dr. Stephen Wells
President
Desert Research Institute

J.8 Reading Rooms and Libraries

U.S. Department of Energy Headquarters Office
Public Reading Room
Washington, D.C.

Pahrump Yucca Mountain Information Center
Pahrump, NV

Esmeralda County Yucca Mountain Oversight Office
Goldfield, NV

Nye County Department of Natural Resources and Federal Facilities
Pahrump, NV

Ms. Susan Beard
Librarian
Northern Arizona University
Cline Library

Ms. Michelle Born
Librarian
Clark County Library
Main Branch
Reference Department

Mr. Bert Chapman
Purdue University
Hesse Library - Documents Department

Ms. Pauline Conner
Administrator
Savannah River Operations

University of South Carolina-Aiken, Gregg-Graniteville Library
Public Reading Room

Ms. Kathy Edwards
Nevada State Library & Archives

Ms. Sandra Groleau
Bates College Library

Ms. Amy Sue Goodin
Associate Director of Research
University of New Mexico
Institute for Public Policy

Ms. Paige Harper
University of Florida
Documents Department

Ms. Deanna Harvey
Strategic Petroleum Reserve Project Management Office
SPRPMO/Reading Room

Mr. John Horst
National Renewable Energy Lab
Public Reading Room

Librarian, Government Documents
University of New Hampshire
Dimond Library

Librarian
San Jose State University
Martin Luther King, Jr. Library
Government Publications Department

Librarian
University of Colorado, Boulder
Library - Government Publications

Librarian
University Library, California State University
Government Documents

Librarian
Susanville District Library

Librarian
Sparks Branch Library

Librarian
Fishlake Branch Library

Librarian
Carson City Library
Reference Department

Librarian
Laughlin Branch Library

Librarian
Needles Library

Librarian
Round Mountain Public Library

Librarian
University of Wisconsin, Madison
Wendt Library - Technical Reports Center

Librarian
University of Texas, San Antonio
Library - Government Documents Department

Mrs. Pat Loper
Great Basin College Library

Mr. Joseph Milazzo
Southern Methodist University
Fondren Library East
Government Information

Ms. Janice Parthree
U.S. Department of Energy
Richland Operations Center
Public Reading Room

Mr. Tim D. Petrosky
Public Affairs Director
Consumer Energy
Big Rock Point

Mr. William H. Schalk
Communications Manager
American Electric Power Company
Cook Visitor Information Center

Ms. Susie Skarl
Head, Government Publications
University of Nevada, Las Vegas
Lied Library

Ms. Barbara Sullivan
Center for Health, Environment and Justice
CHEJ Library

Ms. T. Twyford
Librarian
Tecopa Library

Mr. John Walters
Utah State University
Merrill Library

Lincoln County Nuclear Waste Project Office
Caliente, NV

The University of Nevada Libraries
Business and Government Information Center
Reno, NV

Mr. Dan Barkley
University of New Mexico
Zimmerman Library

Mr. Hui Hua Chua
Michigan State University

Ms. Kay Collins
University of California, Irvine
Langson Library

Ms. Sherry DeDecker
University of California, Santa Barbara
Davidson Library - Government Information
Center

Ms. Heather Elliott
Clearinghouse Coordinator, Nevada State
Clearinghouse
Department of Administration
State of Nevada
Public Reading Room

Ms. Verna Graybill
Librarian
Northwestern Oklahoma State University
J.W. Martin Library Depository

Mr. Michele Hayslett
North Carolina State University Libraries
Government Information Services – RISD

Mr. Mark Holt
Library of Congress
Ms. Alisa Huckle
Mr. Brent Jacobson
Idaho Operations Office
INEEL Technical Library
U.S. DOE Public Reading Room

Mr. Walter Jones
University of Utah
Marriott Library, Special Collections

Librarian
University of Notre Dame
Hesburgh Library - Government Documents Center

Librarian
University of California, Riverside
Rivera Library - Government Publications Department

Librarian
U.S. Geological Survey
Serial Records Unit
National Center

Librarian
Spring Valley Library

Librarian
Billinghurst Middle School Library

Librarian
Inyo County Free Library

Librarian
New Mexico State University
Branson Library – Documents

Librarian
North Las Vegas Public Library

Librarian
Brainerd Memorial Library

Librarian
University of Rhode Island
Library - Government Publications Office

Librarian
University of Maryland, Baltimore County
Albin O. Kuhn Library and Gallery - Government Documents

Mr. Gary Morell
College Hill Library
Rocky Flats Field Office

Mr. Walter Perry
U.S. Department of Energy Information Center
Oak Ridge Operations Office

Ms. Angela Riley
Community Relations Representative
TXU Electric & Gas
Comanche Peak Visitors Center

Mr. John Shuler
Richard J. Daley Library
Documents, Maps and Microforms Department
University of Illinois at Chicago

Mr. Tim Sutherland
Indiana University
Northwest Library, Documents Department

Mr. Carl E. Unger
Senior Communications Representative
Public Information Center
Arizona Public Service Company
Palo Verde Nuclear Generating Station

Ms. Elaine Watson
Boise State University
Library - Government Documents

Ms. Beryl A. Zundel
Sunrise Library

Mr. Bill Zimmerman
U.S. Department of Energy
Bonneville Power Administration
BPA-CILL-1

CONVERSION FACTORS

Metric to English			English to Metric		
Multiply	by	To get	Multiply	by	To get
Area					
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter	1[a]	Parts/million	Parts/million	1[a]	Milligrams/liter
Micrograms/liter	1[a]	Parts/billion	Parts/billion	1[a]	Micrograms/liter
Micrograms/cu. meter	1[a]	Parts/trillion	Parts/trillion	1[a]	Micrograms/cu. meter
Density					
Grams/cu. centimeter	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. centimeter
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Micrometers	0.00003937	Inches	Inches	25,400	Micrometers
Millimeters	0.03937	Inches	Inches	25.40	Millimeters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F – 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2,118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Meters/second	2.237	Miles/hours	Miles/hour	0.44704	Meters/second
Volume					
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1,233.49	Cubic meters
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
English to English					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

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

METRIC PREFIXES

Prefix	Symbol	Multiplication factor		
exa-	E	1,000,000,000,000,000,000	=	10^{18}
peta-	P	1,000,000,000,000,000	=	10^{15}
tera-	T	1,000,000,000,000	=	10^{12}
giga-	G	1,000,000,000	=	10^{9}
mega-	M	1,000,000	=	10^{6}
kilo-	K	1,000	=	10^{3}
deca-	D	10	=	10^{1}
deci-	D	0.1	=	10^{-1}
centi-	C	0.01	=	10^{-2}
milli-	M	0.0 001	=	10^{-3}
micro-	μ=	0.000 001	=	10^{-6}
nano-	N	0.000 000 001	=	10^{-9}
pico-	P	0.000 000 000 001	=	10^{-12}