Appendix C.5

Transportation

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Appendix C.5

Transportation

C.5.1 INTRODUCTION

This appendix supports the results of the transportation analyses presented in Section 5.2.9 of this document. The types of waste being considered are identified in Table C.5-1.

In this environmental impact statement (EIS), the U.S. Department of Energy (DOE) evaluates ***six*** alternatives under which ***twelve*** treatment options occur. The No Action Alternative does not involve shipping and therefore is not analyzed in this appendix. Many options have multiple waste shipments. Within some options different possibilities of shipping and storing waste exist.

Following publication of the Draft EIS, DOE obtained updated information indicating that vitrification of the Idaho National Engineering and Environmental Laboratory (INEEL) mixed high-level waste (HLW) at the Hanford Site would result in a larger volume of HLW glass than was analyzed in the Draft EIS. Under the Minimum INEEL Processing Alternative, DOE had estimated that 730 cubic meters of vitrified mixed HLW (approximately 625 Hanford canisters) would be produced and transported back to the INEEL. DOE now estimates that 3,500 cubic meters of vitrified mixed HLW (approximately 3,000 Hanford canisters) would be produced under that alternative. Tables C.5-1, C.5-11, C.5-12, and C.5-13 present revised transportation impacts for the Minimum INEEL Processing Alternative associated with this larger vitrified waste volume.

C.5.2 ROUTE SELECTION

In order to evaluate transportation impacts, DOE chose reasonable shipment routes to each destination. These routes do not necessarily reflect DOE's ultimate choice, which has yet to be determined.

In addition, the destination for some waste types is not finalized. Class A grout is assumed to be shipped to the Envirocare Facility in Utah, but DOE has not identified an offsite low-level waste disposal facility. ***Because*** the proposed site at Yucca Mountain in Nevada is the only site currently under consideration, DOE assumed that Yucca Mountain is the destination of any HLW ***for*** disposal. Transuranic waste is assumed to be sent to the Waste Isolation Pilot Plant.

The impacts of transporting Class C grout for off-site disposal were analyzed ***as well as*** disposing of this waste at a new INEEL landfill. As with the previously mentioned waste types, the location of a disposal facility for Class C grout has not been selected, but for the purpose of this analysis a ***reasonable*** route to Barnwell, South Carolina is ***evaluated***.

C.5.2.1 Truck Route Selection

Route selection for waste shipments by truck was determined by the HIGHWAY 3.3 computer code (Johnson et al. 1993a). HIGHWAY is a computerized road atlas that details more than 240,000 miles of interstate and other highways. The user can specify the routing criteria to constrain the route selection.

HIGHWAY calculates the total route length and the distances traveled through rural, suburban, and urban population zones. The HIGHWAY code determines population densities (people per square mile) for each of three population zones (urban, suburban, and rural) along the route using 1990 census data.

The HIGHWAY model contains a Waste Isolation Pilot Plant default routing option and a HM-164 option. The HM-164 option, when activated, specifies a route that would comply with the U.S. Department of Transportation regulations for highway route-controlled quantities of radioactive material. The Waste Isolation Pilot Plant default routing option provides the New Mexico-specified routes to the Waste Isolation Pilot Plant. For purposes of this EIS, HIGHWAY was run using the following conditions:

- 70 percent emphasis on time and 30 percent emphasis on mileage
- HM-164 routing for all destinations except New Mexico
- The Waste Isolation Pilot Plant default routing for all shipments to New Mexico

Table C.5-1. Transportation analyses required by alternative.

	Waste type	Origin	Destination	Truck shipments	Rail shipments
Continued Current Operations Alternative					
RH-TRU ***Solids***	110 cubic meters of RH-TRU grout from tank heels packaged in 280 WIPP half-containers at 0.4 cubic meter per half-container	INTEC	WIPP	140	70
Full Separations Option					
Vitrified ***HLW (at INEEL)***	470 cubic meters of vitrified HAW packaged in 780 HLW canisters.	INTEC	NGR	780	160
Class A ***Type*** grout	27,000 cubic meters of Class A grout packaged in 25,100 concrete cylinders of approximately 1 cubic meter each.	INTEC	Envirocare	4,200	1,300
Solidified HAW	250 cubic meters packaged in 1,200 55-gallon drums which are placed into casks.	INTEC	Hanford	80	40
Vitrified ***HLW (at Hanford)***	***3,500*** cubic meters of vitrified HAW packaged in ***3,000*** Hanford HLW canisters.	Hanford	INTEC	***3,000***	***750***
Planning Basis Option					
Vitrified ***HLW (at INEEL)***	470 cubic meters of vitrified HAW packaged in 780 HLW canisters.	INTEC	NGR	780	160
Class A ***Type*** grout	30,000 cubic meters of Class A grout packaged in 27,900 concrete cylinders of approximately 1 cubic meter each.	INTEC	Envirocare	4,700	1,400
RH-TRU ***Solids***	110 cubic meters of RH-TRU grout from tank heels packaged in 280 WIPP half-containers at 0.4 cubic meter per half-container.	INTEC	WIPP	140	70
Transuranic Separations Option					
RH-TRU ***Fraction***	220 cubic meters of granular solids packaged in 550 RH-TRU containers	INTEC	WIPP	280	140
Class C ***Type*** grout	23,000 cubic meters of Class C grout packaged in 21,000 concrete cylinders of approximately 1 cubic meter each.	INTEC	Barnwell	7,000	2,100
Hot Isostatic Pressed Waste Option					
HIP HLW	3,400 cubic meters of HIPed HLW packaged in 5,700 Type B canisters.	INTEC	NGR	5,700	1,100
RH-TRU ***Solids***	110 cubic meters of RH-TRU grout from tank heels packaged in 280 WIPP half-containers at 0.4 cubic meter per half-container.	INTEC	WIPP	140	70

Table C.5-1. Transportation analyses required by alternative (continued).

	Waste type	Origin	Destination	Truck shipments	Rail shipments
	Direct Cement Waste Option				
Cementitious HLW	13,000 cubic meters of cemented HLW packaged in 18,000 Type B canisters.	INTEC	NGR	18,000	3,600
RH-TRU ***Solids***	110 cubic meters of RH-TRU grout from tank heels packaged in 280 WIPP half-containers at 0.4 cubic meter per half-container.	INTEC	WIPP	140	70
	Early Vitrification Option				
Early Vitrified HLW	8,500 cubic meters of vitrified calcine packaged in 11,800 Type B canisters.	INTEC	NGR	12,000	2,400
Early Vitrified RH-TRU	360 cubic meters of vitrified SBW/NGLW packaged in 900 RH-TRU containers.	INTEC	WIPP	450	230
	Steam Reforming Option				
Calcine	***4,400 cubic meters of calcine packaged in 6,100 HLW canisters***	***INTEC***	***NGR***	***6,100***	***1,200***
Steam Reformed SBW	***1,300 cubic meters of steam reformed SBW packaged in 3,300 WIPP half-containers***	***INTEC***	***WIPP***	***1,600***	***810***
NGLW grout	***1,300 cubic meters of NGLW grout packaged in 3,200 containers***	***INTEC***	***WIPP***	***1,600***	***800***
	Minimum INEEL Processing Alternative				
Calcine and Cs IX resin	4,300 cubic meters of calcine and Cs-IX resin (included with calcine) packaged in 3,700 Hanford HLW canisters.	INTEC	Hanford	3,700	920
Grouted CH-TRU	7,500 cubic meters of grouted CH-TRU from SBW packaged in 36,000 55-gallon drums.	INTEC	WIPP	1,300	670
Vitrified ***HLW (at Hanford)***	***3,500*** cubic meters of vitrified HAW packaged in ***3,000*** Hanford HLW canisters.	Hanford	INTEC	***3,000***	***750***
Vitrified ***LLW Fraction (at Hanford)***	14,000 cubic meters of vitrified LAW packaged in 5,600 LAW containers.	Hanford	INTEC	620	310
Vitrified ***HLW (at Hanford)***	***3,500*** cubic meters of vitrified HAW packaged in ***3,000*** Hanford HLW canisters.	INTEC	NGR	***3,000***	***750***
Vitrified ***LLW Fraction (at Hanford)***	14,000 cubic meters of vitrified LAW packaged in 5,600 LAW containers.	INEEL	Envirocare	620	310

Table C.5-1. Transportation analyses required by alternative (continued).

	Waste type	Origin	Destination	Truck shipments	Rail shipments
	Vitrification without Calcine Separations Option				
Vitrified Calcine	***8,500 cubic meters of vitrified calcine packaged in 12,000 HLW canisters.***	***INTEC***	***NGR***	***12,000***	***2,400***
Vitrified SBW	***440 cubic meters of vitrified SBW packaged in 610 HLW canisters.***	***INTEC***	***WIPP***	***610***	***120***
Vitrified SBW	***440 cubic meters of vitrified SBW packaged in 610 HLW canisters.***	***INTEC***	***NGR***	***610***	***120***
NGLW grout	***1,300 cubic meters of NGLW grout packaged in 3,300 WIPP half-containers.***	***INTEC***	***WIPP***	***1,600***	***800***
	Vitrification with Calcine Separations Option				
Class A Type Grout	***24,000 cubic meters of LLW grout packaged in 22,000 concrete cylinders of approximately 1 cubic meter each.***	***INTEC***	***Envirocare***	***3,700***	***1,100***
Vitrified Calcine (separated)	***470 cubic meters of vitrified calcine (separated) packaged in 650 HLW canisters.***	***INTEC***	***NGR***	***650***	***130***
Vitrified SBW	***440 cubic meters of vitrified SBW packaged in 610 HLW canisters.***	***INTEC***	***WIPP***	***610***	***120***
Vitrified SBW	***440 cubic meters of vitrified SBW packaged in 610 HLW canisters.***	***INTEC***	***NGR***	***610***	***120***
NGLW grout	***1,300 cubic meters of NGLW grout packaged in 3,300 WIPP half-containers.***	***INTEC***	***WIPP***	***1,600***	***800***

CH = contact-handled; Cs = cesium; HAW = high-activity waste; HIP = Hot Isostatic Press; NGLW = newly generated liquid waste; NGR = national geologic repository; RH = remote-handled; TRU = transuranic waste; SBW = mixed transuranic waste/SBW; WIPP = Waste Isolation Pilot Plant.

The total distances between all required origins and destinations is presented in Table C.5-2.

C.5.2.2 Rail Route Selection

Rail routes were determined by the INTERLINE 5.0 computer model (Johnson et al. 1993b). The INTERLINE computer model is designed to simulate routing on the U.S. rail system. The INTERLINE database was originally based on data from the Federal Railroad Administration and reflected the U.S. railroad system in 1974. The database has been expanded and modified over the past two decades. The code is updated periodically to reflect current track conditions and has been compared with reported mileages and observations of commercial rail firms.

The INTERLINE model uses the shortest route algorithm that finds the path of minimum impedance within an individual subnetwork. A separate method is used to find paths along the subnetworks. The routes chosen for this study used the standard assumptions in the INTERLINE model to simulate the process of selection that railroads would use to direct shipments of radioactive waste. For sites that do not have direct rail access, the rail site nearest the waste shipment endpoint was used for routing. Population densities along the route are determined using 1990 census data. Table C.5-3 presents the total mileage between INTEC and all waste shipment endpoints.

Table C.5-2. Truck route distances (miles).

	Barnwell	Envirocare	Hanford	INTEC	NGR	WIPP
Barnwell	0	NR	NR	2,400	NR	NR
Envirocare	NR	0	NR	300	NR	NR
Hanford	NR	NR	0	630	NR	NR
INTEC	2,400	300	630	0	750	1,400
NGR	NR	NR	NR	750	0	NR
WIPP	NR	NR	NR	1,400	NR	0

NR = Not required; NGR = national geologic repository; WIPP = Waste Isolation Pilot Plant.

Table C.5-3. Rail route distances (miles).

	Barnwell	Envirocare	Hanford	INTEC	NGR	WIPP
Barnwell	0	NR	NR	2,300	NR	NR
Envirocare	NR	0	NR	300	NR	NR
Hanford	NR	NR	0	690	NR	NR
INTEC	2,300	300	690	0	660	1,500
NGR	NR	NR	NR	660	0	NR
WIPP	NR	NR	NR	1,500	NR	0

NR = Not required; NGR = national geologic repository; WIPP = Waste Isolation Pilot Plant.

C.5.3 VEHICLE-RELATED IMPACTS

This section addresses the impacts of traffic accidents and vehicle emissions associated with transporting each waste type to its destination. These impacts are not related to the radioactive material or hazardous chemicals being transported and would be the same as the impacts from the transportation of nonhazardous material. DOE calculated accident impacts as the number of fatalities that would be expected due to additional vehicle traffic along the proposed routes. Fatalities were calculated on a per shipment basis and were then totaled for all shipments over the transportation period. Calculations were based on the accident statistics and data presented in *State-Level Accident Rates of Surface Freight Transportation: A Reexamination* (Saricks and Tompkins 1999). Impacts from vehicle emissions were calculated as the expected number of excess latent fatalities.

Accident rates used in this assessment were computed for all shipments regardless of cargo. Saricks and Tompkins (1999) point out that shippers and carriers of radioactive material have a higher-than-average awareness of transportation impacts and prepare for such shipments accordingly. These effects were not considered, and accident rates were assumed to be identical to those for normal cargo transport. The accident impacts depend on the total distance traveled in each state and do not rely on national average accident statistics.

In addition to risks from accidents, DOE estimated health risks from vehicle emissions. The distance traveled in an urban population zone and the impact factor for particulate and sulfur dioxide truck exhaust emissions (Rao et al. 1982) were used to estimate urban-area pollution effects due to waste shipments. The impact factor, 1.0×10^{-7}, estimates the number of latent fatalities per kilometer traveled. This impact factor is only valid for urban population zones; therefore, latent fatalities expected from exhaust emissions are only estimated for the total distance that is traveled through urban zones. It should be noted that impacts due to exhaust gases are small relative to impacts from accident fatalities.

C.5.3.1 Truck Impacts

Table C.5-4 presents vehicle-related impacts such as number of accidents for a single round trip between selected points. These values were multiplied by the appropriate number of route shipments (Table C.5-1) to obtain the total impacts reported in ***Table 5.2-13***. All shipments were assumed to be round trip to account for the return of the empty shipping casks. Therefore, the data in Table C.5-4 were created assuming twice the one way mileage shown in Table C.5-2. The expected vehicle pollution latent fatalities were calculated only for distance traveled in urban population zones.

C.5.3.2 Rail Impacts

Table C.5-5 presents vehicle-related impacts for selected rail routes. These values were multiplied by the appropriate number of route shipments (Table C.5.1) to obtain the total impacts reported in Table 5.2-***14***. The expected number of accidents and fatalities per shipment are based on route-specific data and state-specific rail statistics presented in Saricks and Tompkins (1999). Impact factors for latent fatalities due to exhaust emissions from rail transport are not available. For this reason vehicle pollution latent fatalities are omitted from Table C.5-5. All shipments were assumed to be round trip to account for the return of the empty shipping casks. Therefore, the data in Table C.5-5 was calculated assuming twice the one-way mileage shown in Table C.5-3.

C.5.4 CARGO-RELATED INCIDENT-FREE IMPACTS

This section estimates the radiological impacts of incident-free transportation (i.e., no occurrence of accidents) to occupational and public receptors. DOE used the RADTRAN 4 model (Neuhauser and Kanipe 1992) to estimate these impacts. Required route-specific inputs such as the number of miles traveled, population densities adjacent to shipping routes, and the number of miles traveled in each of the population zones (urban, suburban, and rural) were determined using the HIGHWAY and INTERLINE models described in Section C.5.2.

Four radiation exposure scenarios were analyzed using the RADTRAN 4 code as follows:

- Along Route: Exposure to members of the public who reside adjacent to routes of travel

Table C.5-4. Vehicle-related impacts per round-trip shipment for trucks.

Originating site	Destination	Impact category	Total
INTEC	Barnwell	Accidents	3.5×10^{-3}
		Fatalities	1.4×10^{-4}
		Vehicle pollution LFs	1.3×10^{-5}
	Envirocare	Accidents	3.5×10^{-4}
		Fatalities	1.8×10^{-5}
		Vehicle pollution LFs	1.8×10^{-6}
	Hanford	Accidents	6.3×10^{-4}
		Fatalities	4.3×10^{-5}
		Vehicle pollution LFs	1.1×10^{-6}
	NGR	Accidents	7.7×10^{-4}
		Fatalities	3.5×10^{-5}
		Vehicle pollution LFs	5.5×10^{-6}
	WIPP	Accidents	1.7×10^{-3}
		Fatalities	6.5×10^{-5}
		Vehicle pollution LFs	5.0×10^{-6}

LF = latent fatality; NGR = national geologic repository; WIPP = Waste Isolation Pilot Plant.

Table C.5-5. Vehicle-related impacts per round-trip shipment for rail.

Originating site	Destination	Impact category	Total per shipment
INTEC	Barnwell	Accidents	3.2×10^{-4}
		Fatalities	6.1×10^{-5}
	Envirocare	Accidents	5.9×10^{-5}
		Fatalities	1.7×10^{-5}
	Hanford	Accidents	1.7×10^{-4}
		Fatalities	2.3×10^{-5}
	NGR	Accidents	1.0×10^{-4}
		Fatalities	3.1×10^{-5}
	WIPP	Accidents	1.6×10^{-4}
		Fatalities	3.1×10^{-5}

NGR = national geologic repository ; WIPP = Waste Isolation Pilot Plant.

- Sharing Route: Exposure to members of the public sharing the right of way

- Stops: Exposure to members of the public while shipments are at rest stops

- Occupational: Exposure to vehicle crews

Among the more sensitive RADTRAN input parameters is the Transport Index. The Transport Index represents the radiation dose at one meter away from the surface of the shipping package. The maximum radiation dose permissible is 10 millirems per hour at 2 meters for exclusive-use shipments. For this analysis, the 2-meter regulatory limit was used to calculate the maximum allowable dose at 1 meter (Transport Index). Since the Transport Index is dependent on the number of packages per shipment and the package dimension, a value for Transport Index was calculated for each of the various packages associated with the different waste forms that would be shipped. The Transport Index ranged from a high of 16.9 for truck transport of solidified high-activity waste to a low of 0.31 for rail transport of contact-handled transuranic waste. Many of the other inputs are dependent on the mode of transportation and are discussed in the following sections.

The incident-free impacts estimated from RADTRAN are in units of person-rem. These can be converted into latent cancer fatalities using conversion factors. For nonoccupational doses, 1 person-rem is expected to cause 5×10^{-4} latent cancer fatalities, and for occupational doses 1 person-rem is expected to cause 4×10^{-4} latent cancer fatalities (ICRP 1991).

C.5.4.1 Truck Impacts

In addition to the RADTRAN inputs described in Section C.5.4, other unique parameters can affect truck shipments. The vehicle speed was assumed to be 15, 25, and 55 miles per hour in urban, suburban, and rural zones, respectively. DOE believes that these speeds actually underestimate the probable speed of the truck through each of the population zones. This assumption results in a conservative overestimation of exposure and also accounts for the possibility of speed reductions due to traffic.

With the exception of shipments between the INEEL and Envirocare, all truck shipments were assumed to have 0.011 hours of stopping time for every kilometer traveled. This accounts for overnight stopping. ***Because*** the trip from the INEEL to Envirocare is not long enough to require an overnight stop, the total stopping time assumed for shipments from the INEEL to Envirocare is 0.167 hours (10 minutes).

During transport the distance between the waste and the crew is assumed to be 10 meters. During stops, there are an assumed 50 members of the public present located 20 meters from the waste.

C.5.4.2 Rail Impacts

In addition to the RADTRAN inputs described in Section C.5.4, there are other parameters which are unique to rail shipments. The train speed was assumed to be 15, 25, and 40 miles per hour in urban, suburban, and rural zones, respectively.

With the exception of shipments between the INEEL and Envirocare, all rail shipments were assumed to have 0.033 hours of stopping time for every kilometer traveled. This accounts for overnight stopping. ***Because*** the trip from INEEL to Envirocare is not long enough to require an overnight stop, the total stopping time for shipments from the INEEL to Envirocare is 0.167 hours (10 minutes).

During transport, the distance between the waste and the crew is assumed to be 152 meters. An assumed 100 members of the public are present at the stops at 20 meters from the waste.

C.5.5 CARGO-RELATED ACCIDENT IMPACTS

This section presents the impacts due to transportation accidents in which an environmental release of radioactive material occurs. Radiological impacts were evaluated considering the probability of a given accident occurring and the consequences of that accident. The RADTRAN 4 model estimates the collective accident risk to populations by considering the spectrum of possible accidents and summing the results for each type of accident. The estimates in Section 5.2.9 do not show the risk from a given accident occurring but present the total expected impacts considering the probability and consequences of all accidents. For the maximally exposed individual, DOE used the RISKIND code to calculate the radiation dose from accidents (see Section C.5.5.5).

C.5.5.1 Accident Types

All accidents can be represented by a spectrum of severity classes ranging from those considered least severe to most severe. The severity class of an accident is dependent on the crush force or impact speed and the duration of a 1,300-degree Kelvin fire (NRC 1977). Two sets of accident severity categories and associated conditional probabilities were used in assessing cargo-related accident impacts for this analysis. All vitrified waste and waste forms similar to vitrified wastes (e.g., hot isostatic pressed waste) were analyzed using a methodology based on studies performed in support of NUREG/CR-4829 (Fisher et al. 1988) (i.e., the Modal Study) (Ross 1999). This study represents the most recently developed methodology for assessing cargo-related accident impacts and is used for the transportation analysis performed for the Yucca Mountain Repository EIS. Since the study only considers the transport of spent nuclear fuel and vitrified HLW wastes, a second methodology, that found in NUREG-0170 (NRC 1977), was used for the remaining radioactive waste forms being considered in this EIS. For both of these methods, each accident severity category has an associated conditional probability. The conditional probabilities represent the likelihood that an accident will involve the mechanical forces and the heat energy associated with each of the categories.

Table C.5-6 shows what fraction of the total accidents would be expected to be from each severity category, as based on NUREG-0170. For example, of all possible truck accidents that may occur, 55 percent would be classified as a level one severity accident. According to these fractional occurrences, a level one accident occurs more often but is the least severe while a level eight is highly unlikely but is the most severe. The table also represents the fraction of all accidents of that type that could occur in each of the population density zones. Of all expected level one severity accidents, 10 percent would occur in the rural population density zone, another 10 percent would occur in the suburban zone, and 80 percent would occur in the urban population density zone.

Table C.5-7 presents the accident conditional occurrence probabilities for truck and rail transport of vitrified HLW wastes. There are only six accident severity categories used in this methodology. Table C.5-7 shows that 99 percent of all truck and rail accidents would be a Category 1 severity event; in comparison, accidents of a Category 2 through 6 severity are very unlikely

Table C.5-6. Accident conditional probability of occurrences (NUREG-0170 methodology). [a]

Accident severity category	Fractional occurrences	Rural	Suburban	Urban
		Truck		
1	0.55	0.1	0.1	0.8
2	0.36	0.1	0.1	0.8
3	0.07	0.3	0.4	0.3
4	0.02	0.3	0.4	0.3
5	2.8×10^{-3}	0.5	0.3	0.2
6	1.1×10^{-3}	0.7	0.2	0.1
7	8.5×10^{-5}	0.8	0.1	0.1
8	1.5×10^{-5}	0.9	0.05	0.05
		Rail		
1	0.50	0.1	0.1	0.8
2	0.30	0.1	0.1	0.8
3	0.18	0.3	0.4	0.3
4	0.02	0.3	0.4	0.3
5	1.8×10^{-3}	0.5	0.3	0.2
6	1.3×10^{-4}	0.7	0.2	0.1
7	6.0×10^{-5}	0.8	0.1	0.1
8	1.0×10^{-5}	0.9	0.05	0.05

a. Source: NRC (1977).

Table C.5-7. Accident conditional probability of occurrences (Modal-related methodology). [a]

Accident severity category	Conditional Probability	
	Truck	Rail
1	0.99	0.99
2	4.1×10^{-5}	2.0×10^{-3}
3	3.8×10^{-3}	1.3×10^{-6}
4	1.8×10^{-3}	5.6×10^{-4}
5	1.6×10^{-5}	6.1×10^{-4}
6	9.8×10^{-6}	1.3×10^{-4}

a. Source: Ross (1999).

to occur. The distribution of each accident severity category by population density zones is not considered in the Modal-support study.

C.5.5.2 Accident Release

As with the accident severity categories and conditional probabilities discussed in the previous section, accident releases were calculated using two methodologies: the method derived from NUREG/CR-4829 (Fisher et al. 1988) and the method presented in NUREG-0170 (NRC 1977). For both of these approaches, three factors were used to determine the amount the material that is released into the environment and available for inhalation. These factors include the release fraction, the aerosolized fraction, and the respirable fraction.

The release fraction is the fraction of material that would be released from the shipping container in an accident of a given severity category. The release fraction is dependent on the container. For the analyses in this EIS, DOE used four sets of release fractions (Tables C.5-8 and C.5-9). For vitrified HLW and wastes with physical characteristics similar to vitrified HLW (such as HIPed HLW), DOE used the release fractions reported in NUREG/CR-4829, referred to as the Modal Study. The Modal Study release fractions are based on the assumption that the stainless steel canister would limit the quantity of waste material that would be released, even in the most severe accidents. For vitrified, remote-handled, transuranic waste (RH-TRU solids and RH-TRU fraction), DOE used release fractions from the Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement (DOE 1997). For Class A-type grout, DOE used the release fractions for a Type A container as reported in NUREG-0170. For all other wastes, DOE used the release fractions for a Type B container as reported in NUREG-0170.

The aerosolized fraction represents the fraction of the material released in an accident of a given severity that becomes aerosolized. The respirable fraction represents the fraction of aerosolized material that could be inhaled. Both of these factors are dependent on the physical and chemical characteristics of the waste form. Table C.5-10 shows the aerosolized and respirable fractions for each of the radioactive waste forms considered in this transportation analysis. The vitrified waste forms all have aerosolized and respirable fractions equal to 1.0 since these factors have already been taken into account in the release fractions developed for the Modal Study support model.

Table C.5-8. Estimated release fractions.

Accident severity category	***Class A Grout***[a]	Type B container[a]	***Vitrified*** RH-TRU[b]
1	***0***	0	0
2	***0.01***	0	0
3	***0.1***	0. 01	6×10^{-9}
4	***1***	0.1	2×10^{-7}
5	***1***	1	1×10^{-4}
6	***1***	1	1×10^{-4}
7	***1***	1	2×10^{-4}
8	***1***	1	2×10^{-4}

a. Source: NRC (1977).
b. Source: DOE (1997), ***fraction includes respirable and aerosolized fractions.***
RH = remote handled ; TRU = transuranic waste.

Table C.5-9. Estimated release fractions (Modal-related methodology).[a]

Accident severity category	Release fraction
1	0
2	0
3	7.0×10^{-9}
4	4.0×10^{-6}
5	4.0×10^{-6}
6	4.0×10^{-6}

a. Source: Ross (1999).

Table C.5-10. Aerosolized and respirable fractions.

Physical waste form	Aerosolized fractions	Respirable fractions
Vitrified ***wastes***[a]	1.0	1.0
Grouted wastes[b]	0.05	0.05
Solidified HAW[b]	***0.1***	0.05
HIP HLW[a]	1.0	1.0
Cementitious HLW[b]	0.05	0.05
Calcine and Cs ion exchange resin[b]	0.1	0.05
Steam Reformed SBW[b]	***0.1***	***0.05***
RH-TRU ***Solids and Fractions***	***0.1***	***0.05***

a. Source: Ross (1999).
b. Source: NRC (1977).
HAW = high-activity waste; HIP = hot isostatic pressed; Cs = cesium; RH = remote handled ; TRU = transuranic waste.

C.5.5.3 Radiological Waste Characterization

In order to determine the potential cargo-related impacts from accidents, DOE estimated the radiological content of each waste type (Table C.5-11). The total amount of material available to receptors was determined by multiplying the total radiological content of a shipment by the release factor that corresponds to each type of accident.

C.5.5.4 Exposure Pathways for Released Material

RADTRAN 4 assumes that the material available to the receptor in any given accident is dispersed into the environment according to standard Gaussian diffusion models. Default data for atmospheric dispersion were used, representing an instantaneous ground-level release and a small diameter source cloud. The calculation of the collective population dose after the release and dispersal of radioactive material includes the following pathways:

- External exposure to a passing radioactive cloud
- External exposure to contaminated soil
- Internal exposure from inhaling airborne contaminants

C.5.5.5 Radiological Consequence Assessment Using RISKIND

The RISKIND version 1.11 (Yuan et al. 1995) assessment was configured to provide consequences under the two most frequent atmospheric surface layer conditions existing in the contiguous United States: neutral and stable. Neutral (Pasquill stability class 'D') conditions exist nearly half the time with prevalent wind speeds ranging between 4 and 7 meters per second; stable conditions (Pasquill stability classes 'F' and 'G') about one-fifth of the time with a wind speed below 1 meter per second (TRW 1998). These joint atmospheric stability and wind speed conditions dictate how much of the radioactive material released from an assumed failed waste package ultimately reaches an affected individual. The neutral and stable atmospheric transport conditions were emulated in RISKIND by selecting the D and F Pasquill stability classes with respective wind speeds of 5.7 and 0.9 meters per second.

The receptor defined for purposes of this analysis was an adult member of the public located outdoors at the location of maximum exposure to the wind-borne plume of radioactive material (the "critical receptor" location). Using RISKIND, the distance from the truck or rail accident site to the unshielded critical receptor was calculated to be <0.1 and 0.6 kilometers under neutral and stable atmospheric stability conditions, respectively. This critical receptor or

Table C.5-11. Radioactivity of each waste type (curies per container).

	Class A ***Type*** grout[a]	***Vitrified HLW*** (at INEEL)[b]	Solidified HAW[c]	***Vitrified HLW*** (at Hanford)[d]	HIP HLW[e]	Cementitious ***HLW***[f]	Early Vitrified ***HLW***[g]	Calcine and Cs IX resin[h]	***Vitrified LLW Fraction*** (at Hanford)[d]
Am-241	0.0052	12	2.6	***2.7***	1.6	0.51	0.77	2.5	0.14
Am-243	8.1×10^{-9}	1.8×10^{-5}	3.9×10^{-6}	***7.9×10^{-6}***	4.6×10^{-6}	1.5×10^{-6}	2.2×10^{-6}	7.2×10^{-6}	4.1×10^{-7}
Ba-137m	0.29	1.8×10^{-4}	4.0×10^{-5}	-	1.6×10^{3}	510	770	2.5×10^{3}	-
Cd-113m	-	-	-	-	0.067	0.021	0.032	0.1	-
Ce-144	3.7×10^{-4}	16	3.4	-	2.3	0.72	5.3×10^{-18}	1.7×10^{-17}	-
Cm-242	1.3×10^{-8}	2.9×10^{-5}	6.3×10^{-6}	-	3.9×10^{-6}	1.2×10^{-6}	1.9×10^{-6}	6.1×10^{-6}	-
Cm-244	2.4×10^{-8}	5.4×10^{-5}	1.2×10^{-5}	***1.4×10^{-5}***	7.3×10^{-6}	2.3×10^{-6}	3.5×10^{-6}	1.1×10^{-5}	1.4×10^{-7}
Co-60	0.07	2.4×10^{-5}	5.3×10^{-6}	-	0.16	0.050	0.024	0.076	-
Cs-134	0.0029	1.3×10^{-6}	2.8×10^{-7}	-	1.9	0.61	1.2×10^{-3}	3.9×10^{-3}	-
Cs-135	4.1×10^{-6}	4.6×10^{-9}	9.9×10^{-10}	***0.052***	0.027	8.6×10^{-3}	0.013	0.043	2.1×10^{-4}
Cs-137	0.34	13,000	2,800	***3.3×10^{3}***	1.8×10^{3}	570	820	2.6×10^{3}	13
Eu-152	1.3×10^{-4}	0.35	0.077	-	0.048	0.015	0.023	0.075	-
Eu-154	0.010	28	6.2	-	3.8	1.2	1.8	5.8	-
Eu-155	9.4×10^{-5}	0.82	0.18	-	0.17	0.054	0.014	0.044	-
I-129	8.9×10^{-5}	0.020	0.0036	-	1.9×10^{-3}	5.9×10^{-4}	5.6×10^{-4}	1.8×10^{-3}	-
Nb-93m	-	-	-	-	0.093	0.029	0.045	0.14	-
Ni-63	0.0093	1.0×10^{-4}	2.2×10^{-5}	-	-	-	-	-	-
Np-237	3.1×10^{-14}	0.030	0.054	***2.1×10^{-3}***	2.5×10^{-3}	7.8×10^{-4}	7.4×10^{-4}	2.4×10^{-3}	1.6×10^{-4}
Pa-233	3.8×10^{-15}	0.010	0.0025	-	1.5×10^{-3}	4.8×10^{-4}	7.4×10^{-4}	2.4×10^{-3}	-
Pd-107	-	-	-	-	7.6×10^{-4}	2.4×10^{-4}	3.7×10^{-4}	1.2×10^{-3}	-
Pm-147	0.0017	3.7	-	-	0.51	0.16	0.25	0.79	-
Pr-144	-	-	-	-	0.51	0.16	0.25	0.8	-
Pu-238	5.1×10^{-10}	100	22	***23***	14	4.3	6.5	0.21	0.85
Pu-239	1.0×10^{-11}	2.4	0.52	***0.48***	0.31	0.097	0.13	0.41	0.017
Pu-240	7.9×10^{-12}	1.6	0.36	***0.38***	0.22	0.070	0.10	0.33	0.014
Pu-241	2.4×10^{-10}	50	10.7	***12***	6.6	2.1	3.0	9.7	0.13
Pu-242	1.6×10^{-14}	0.0032	7.0×10^{-4}	-	4.3×10^{-4}	1.4×10^{-4}	2.1×10^{-4}	6.7×10^{-4}	-
Ru-106	0.22	0.14	0.031	***9.0×10^{-14}***	0.92	0.29	3.0×10^{-14}	9.8×10^{-14}	2.5×10^{-15}
Sb-125	0.050	1.9×10^{-5}	4.2×10^{-6}	-	0.20	0.062	7.5×10^{-3}	0.024	-
Sb-126	-	-	-	-	2.5×10^{-3}	8.0×10^{-4}	1.2×10^{-3}	3.9×10^{-3}	-
Se-79	-	-	-	-	0.021	6.5×10^{-3}	0.010	0.032	-
Sm-151	0.52	250	55	***67***	36	11	17	0.56	0.40
Sn-121m	-	-	-	-	1.0×10^{-3}	3.3×10^{-4}	5.0×10^{-4}	1.6×10^{-3}	-
Sn-126	-	-	-	-	0.018	5.8×10^{-3}	8.8×10^{-3}	0.028	-
Sr-90	5.4×10^{-5}	1.4×10^{4}	3.1×10^{3}	***3.5×10^{3}***	1.9×10^{3}	600	920	2.9×10^{3}	34
Tc-99	0.090	2.8	0.60	***0.25***	0.70	0.22	0.34	1.1	0.59
Th-230	3.0×10^{-5}	3.4×10^{-5}	7.4×10^{-6}	***2.3×10^{-4}***	1.2×10^{-4}	3.8×10^{-5}	5.8×10^{-5}	1.9×10^{-4}	1.6×10^{-6}
Th-231	2.2×10^{-5}	2.5×10^{-5}	5.4×10^{-6}	-	8.9×10^{-5}	2.8×10^{-5}	4.3×10^{-5}	1.4×10^{-4}	-
U-232	6.3×10^{-20}	5.9×10^{-6}	1.3×10^{-6}	-	-	-	-	-	-
U-233	1.2×10^{-17}	9.4×10^{-4}	2.0×10^{-4}	***3.8×10^{-7}***	9.3×10^{-5}	2.9×10^{-5}	1.0×10^{-7}	3.3×10^{-7}	1.1×10^{-8}
U-234	1.4×10^{-15}	0.10	0.022	***0.025***	0.014	4.4×10^{-3}	6.7×10^{-3}	0.022	7.4×10^{-4}
U-235	1.0×10^{-17}	7.6×10^{-4}	1.6×10^{-4}	***1.6×10^{-4}***	9.9×10^{-5}	3.1×10^{-5}	4.3×10^{-5}	1.4×10^{-4}	4.7×10^{-6}
U-236	2.4×10^{-17}	0.0017	3.7×10^{-4}	-	2.3×10^{-4}	7.3×10^{-5}	1.1×10^{-4}	3.6×10^{-4}	-
U-237	2.0×10^{-17}	1.1×10^{-3}	2.4×10^{-4}	-	1.5×10^{-4}	4.8×10^{-5}	7.3×10^{-5}	2.4×10^{-4}	-
U-238	2.4×10^{-18}	1.8×10^{-4}	3.9×10^{-5}	***8.3×10^{-6}***	1.9×10^{-5}	6.1×10^{-6}	2.2×10^{-6}	7.1×10^{-6}	2.4×10^{-7}
Y-90	5.1×10^{-7}	1.4×10^{4}	3.0×10^{3}	***3.5×10^{3}***	1.9×10^{3}	600	920	2.9×10^{-3}	34
Zr-93	-	-	-	-	0.11	0.034	0.051	0.17	-

a. Source: Landman and Barnes (1998).
b. Source: Landman (1998), Fluor Daniel (1997).
c. Source: Quigley and Keller (1998), Landman (1998).
d. Source: Jacobs (1998). ***Scaled for new waste volumes.***
e. Source: Barnes (1998a), Dafoe and Losinski (1998), Fluor Daniel (1997), Russell et al. (1998a,b).
f. Source: Barnes (1998a), Fluor Daniel (1997), Russell et al. (1998a,b)
g. Source: Barnes (1998a,b), Fewell (1999), Lee (1999).
h. Source: Barnes (1998a,b), Lopez (1998).

Table C.5-11. Radioactivity of each waste type (curies per container) (continued).

	Class C *Type* grout[a]	*Early* Vitrified RH-TRU[i]	*Grouted* CH-TRU[j]	RH-TRU *Fraction*[k]	***Vitrified calcine[l] (separated)***	***Vitrified calcine[m]***	***Vitrified SBW[n]***	***NGLW grout[o]***	***Steam Reformed SBW[p]***	***RH-TRU Solids[q]***	***Calcine[h]***
Am-241	5.4×10^{-3}	0.22	0.060	18	14	0.77	0.32	0.15	0.059	0.32	1.5
Am-243	8.3×10^{-9}	8.7×10^{-5}	2.7×10^{-5}	2.4×10^{-5}	2.1×10^{-5}	2.2×10^{-6}	1.3×10^{-4}	5.9×10^{-5}	2.4×10^{-5}	1.1×10^{-4}	4.4×10^{-6}
Ba-137m	440	150	3.6×10^{-3}	5.2×10^{-5}	2.1×10^{-4}	770	220	12	41	250	1.5×10^{3}
Cd-113m	-	7.4×10^{-3}	-	-	-	0.032	0.011	-	2.0×10^{-3}	-	0.064
Ce-144	4.0×10^{-4}	2.5×10^{-8}	2.0×10^{-4}	21	19	5.3×10^{-18}	3.7×10^{-8}	2.4×10^{-7}	6.8×10^{-9}	0.070	1.0×10^{-17}
Cm-242	1.3×10^{-8}	5.0×10^{-5}	1.5×10^{-4}	3.9×10^{-5}	3.5×10^{-5}	1.9×10^{-6}	7.4×10^{-5}	4.8×10^{-6}	1.4×10^{-5}	6.1×10^{-5}	3.8×10^{-6}
Cm-244	2.5×10^{-8}	4.4×10^{-3}	2.7×10^{-3}	7.1×10^{-5}	6.4×10^{-5}	3.5×10^{-6}	6.5×10^{-3}	4.9×10^{-5}	1.2×10^{-3}	9.7×10^{-3}	7.0×10^{-6}
Co-60	0.072	0.027	0.021	3.5×10^{-9}	2.9×10^{-5}	0.024	0.040	0.017	7.4×10^{-3}	0.18	0.047
Cs-134	0.16	1.1×10^{-3}	5.6×10^{-5}	1.1×10^{-9}	1.6×10^{-6}	1.2×10^{-3}	1.6×10^{-3}	2.8×10^{-3}	3.0×10^{-4}	3.3	2.4×10^{-3}
Cs-135	7.6×10^{-3}	3.7×10^{-3}	5.8×10^{-8}	1.1×10^{-9}	5.5×10^{-9}	0.013	5.4×10^{-3}	2.5×10^{-4}	1.0×10^{-3}	4.3×10^{-3}	0.026
Cs-137	470	150	3.8×10^{-3}	5.5×10^{-5}	1.6×10^{4}	820	220	13	41	260	1.6×10^{3}
Eu-152	1.7×10^{-4}	5.4×10^{-3}	2.7×10^{-4}	0.50	0.42	0.023	8.0×10^{-3}	9.1×10^{-4}	1.5×10^{-3}	0.014	0.046
Eu-154	0.013	0.24	0.020	43	33	1.8	0.35	0.054	0.065	0.60	3.6
Eu-155	9.6×10^{-5}	0.11	0.019	1.1	0.98	0.014	0.16	0.022	0.030	1.3	0.027
I-129	4.7×10^{-4}	0.034	2.3×10^{-4}	8.3×10^{-3}	0.024	5.6×10^{-4}	0.050	4.0×10^{-5}	9.2×10^{-3}	2.6×10^{-4}	1.1×10^{-3}
Nb-93m	-	7.7×10^{-3}	-	-	-	0.045	0.011	-	2.0×10^{-3}	-	0.089
Ni-63	9.8×10^{-3}	0.12	5.7×10^{-3}	5.9×10^{-11}	1.2×10^{-4}	-	0.18	0.016	0.033	0.16	-
Np-237	3.8×10^{-14}	0.012	6.9×10^{-5}	0.034	0.036	7.4×10^{-4}	0.018	5.1×10^{-4}	3.3×10^{-3}	7.4×10^{-4}	1.5×10^{-3}
Pa-233	3.8×10^{-14}	0.012	-	0.034	0.012	7.4×10^{-4}	0.018	-	3.3×10^{-3}	-	1.5×10^{-3}
Pd-107	-	6.7×10^{-5}	-	-	-	3.7×10^{-4}	9.9×10^{-5}	-	1.8×10^{-5}	-	7.3×10^{-4}
Pm-147	1.7×10^{-3}	0.023	0.11	5.5	4.4	0.25	0.034	0.031	6.3×10^{-3}	2.1	0.49
Pr-144	-	2.5×10^{-8}	9.8×10^{-3}	-	-	0.25	3.7×10^{-8}	2.4×10^{-7}	6.8×10^{-9}	0.070	0.49
Pu-238	5.7×10^{-10}	1.4	0.092	150	120	6.5	2.1	0.27	0.39	6.6	13
Pu-239	1.1×10^{-11}	0.23	9.6×10^{-3}	3.5	2.9	0.13	0.34	0.021	0.063	0.59	0.25
Pu-240	9.1×10^{-12}	0.044	3.2×10^{-3}	2.4	1.9	0.10	0.065	6.1×10^{-3}	0.012	0.051	0.20
Pu-241	2.7×10^{-10}	0.57	0.060	69	60	3.0	0.84	0.12	0.016	5.2	6.0
Pu-242	1.8×10^{-14}	3.3×10^{-5}	1.8×10^{-6}	4.8×10^{-3}	3.8×10^{-3}	2.1×10^{-4}	4.9×10^{-5}	4.5×10^{-6}	9.1×10^{-6}	3.8×10^{-5}	4.1×10^{-4}
Ru-106	0.23	5.0×10^{-7}	5.3×10^{-4}	0.19	0.17	3.0×10^{-14}	7.4×10^{-7}	3.7×10^{-6}	1.4×10^{-7}	0.051	6.0×10^{-14}
Sb-125	0.051	2.1×10^{-3}	8.2×10^{-3}	1.3×10^{-9}	2.3×10^{-5}	7.5×10^{-3}	3.1×10^{-3}	2.5×10^{-3}	5.7×10^{-4}	25	0.015
Sb-126	-	2.4×10^{-4}	-	-	-	1.2×10^{-3}	3.5×10^{-4}	-	6.5×10^{-5}	-	2.4×10^{-3}
Se-79	-	1.8×10^{-3}	-	-	-	0.010	2.7×10^{-3}	-	5.0×10^{-4}	-	0.020
Sm-151	0.53	1.3	0.059	350	300	17	1.9	0.16	0.35	1.7	34
Sn-121m	-	2.3×10^{-4}	-	-	-	5.0×10^{-4}	3.4×10^{-4}	-	6.3×10^{-5}	-	9.9×10^{-4}
Sn-126	-	1.7×10^{-3}	-	-	-	8.8×10^{-3}	2.5×10^{-3}	-	4.6×10^{-4}	-	0.017
Sr-90	520	160	3.3	1.2×10^{-4}	1.7×10^{4}	920	240	10	44	180	1.8×10^{3}
Tc-99	0.19	0.040	1.7×10^{-3}	0.41	3.3	0.34	0.059	4.8×10^{-3}	0.011	0.90	0.67
Th-230	3.2×10^{-5}	3.7×10^{-6}	1.8×10^{-8}	4.6×10^{-5}	4.1×10^{-5}	5.8×10^{-5}	5.4×10^{-6}	1.3×10^{-7}	1.0×10^{-6}	3.8×10^{-6}	1.2×10^{-4}
Th-231	2.3×10^{-5}	8.7×10^{-5}	3.1×10^{-3}	3.6×10^{-5}	3.0×10^{-5}	4.3×10^{-5}	1.3×10^{-4}	-	2.4×10^{-5}	-	8.6×10^{-5}
U-232	1.2×10^{-19}	7.7×10^{-6}	3.6×10^{-7}	8.5×10^{-6}	7.0×10^{-6}	-	1.1×10^{-5}	6.3×10^{-7}	2.0×10^{-6}	9.3×10^{-6}	-
U-233	1.3×10^{-17}	1.0×10^{-6}	2.8×10^{-10}	1.3×10^{-3}	1.1×10^{-3}	1.0×10^{-7}	1.5×10^{-6}	2.1×10^{-9}	2.8×10^{-7}	1.6×10^{-7}	2.0×10^{-7}
U-234	2.1×10^{-15}	3.4×10^{-3}	1.6×10^{-4}	0.15	0.12	6.7×10^{-3}	5.0×10^{-3}	3.1×10^{-4}	9.2×10^{-4}	2.9×10^{-3}	0.013
U-235	1.5×10^{-17}	8.7×10^{-5}	4.1×10^{-6}	1.1×10^{-3}	9.1×10^{-4}	4.3×10^{-5}	1.3×10^{-4}	8.0×10^{-6}	2.4×10^{-5}	1.0×10^{-4}	8.6×10^{-5}
U-236	3.4×10^{-17}	1.4×10^{-4}	7.9×10^{-6}	2.5×10^{-3}	2.0×10^{-3}	1.1×10^{-4}	2.1×10^{-4}	1.5×10^{-5}	3.9×10^{-5}	1.8×10^{-4}	2.2×10^{-4}
U-237	2.3×10^{-17}	1.4×10^{-5}	-	1.6×10^{-3}	1.3×10^{-3}	7.3×10^{-5}	2.1×10^{-5}	-	3.9×10^{-6}	-	1.4×10^{-4}
U-238	2.8×10^{-18}	8.7×10^{-5}	2.9×10^{-6}	2.6×10^{-4}	2.1×10^{-4}	2.2×10^{-6}	1.3×10^{-4}	8.1×10^{-6}	2.4×10^{-5}	2.0×10^{-5}	4.4×10^{-6}
Y-90	510	0.016	2.1	1.2×10^{-4}	1.8×10^{4}	920	0.024	10	4.4×10^{-3}	180	1.8×10^{3}
Zr-93	-	9.1×10^{-3}	-	-	-	0.051	0.013	-	2.4×10^{-3}	-	0.10

i. Source: Wenzel (1997).
j. Source: Barnes (1998c).
k. Source: Russell et al. (1998a).
l. Source: Landman (1998), Fluor Daniel (1997).
m. Source: Barnes (1998a,b), Fewell (1999), Lee (1999).
n. Source: Wenzel (1997).
o. Source: Derived from Millet (2001).
p. Scaled from vitrified SBW.
q. Source: Kimmitt (2002).

Cs IX = cesium ion exchange; HAW = high-activity waste; HIP = Hot Isostatic Press; LLW = low-level waste ; NGLW = newly generated liquid waste; TRU = transuranic waste; CH = contact-handled; RH = remote-handled ; SBW = mixed transuranic waste/SBW.

maximally exposed individual was assumed to be exposed to the plume's radioactive contents for two hours before being evacuated or otherwise leaving the affected area. Thus, the individual's consequence (total effective dose equivalent or TEDE) was derived solely from a short-term (2-hour) scenario of direct radiation exposure from the shipment, breathing contaminated air, being submerged by contaminated air ("cloudshine"), and standing on contaminated ground ("groundshine"). Long-term exposure conditions such as eating food or water contaminated by the plume or receiving medical care to reduce the amount of radioactive material present in the body were not considered by DOE to be reasonably foreseeable and thus were not included in this analysis.

The type and amount of radioactive material released from each of the ***20*** waste package categories assumed to fail in an accident was taken or adapted from the complementary RADTRAN 4 input files. All radioactivity data used was based on the unit source terms listed in Table C.5-11. The RADTRAN 4 waste package failure data used included the smallest "moderate severity" and highest "extreme severity" non-zero release fractions and the respective respirable aerosol estimators. The range of values from which the release estimators were selected is shown in Tables C.5-8 through C.5-10, which are based on NUREG-0170 and Modal-related (NUREG/CR-4829) methodologies. These two accident severity categories were chosen to portray the complete range of consequences for accidents involving release of radioactive material. To restrict the influence of waste package design and preparation on close-in direct radiation exposures, the RISKIND assessment reflected exclusive-use shipments with a 2-meter dose rate set at the Department of Transportation limit of 10 mrem per hour. Waste package dimensions for this direct radiation exposure portion of the assessment were assumed to be the same as those used for the RADTRAN analysis.

For multiple waste package shipments, it was simply assumed that one-quarter of the waste packages would fail during an accident (in all cases, at least one package was assumed to leak some or all of it's contents). Lacking verifiable information on the failure behavior of multiple INEEL waste package shipments, DOE believes that this assumption is a reasonable compensating measure. This assumption alone accounts for the differences observed in the truck and rail consequence results for each waste form shipped. RISKIND was also configured to include the effects of a moderate fire (corresponding to diesel fuel burning at a rate of about one gallon per minute) on the transport and diffusion of radioactive material from the accident site to the critical receptor. All other RISKIND parameter values were left at their default settings.

The results of the consequence analyses are shown in Tables C.5-12 and C.5-13 for moderate and extreme severity truck and rail accidents, respectively. Under moderate accident severity conditions, the critical receptor dose ranges from ***2.1×10^{-8}*** (***NGLW Grout by rail***, stable atmosphere) to ***0.36*** rem (solidified HAW by rail, neutral atmosphere). For these same shipments under extreme severity accident conditions, the critical receptor dose ranges from ***3.8×10^{-6}*** (***NGLW Grout by rail***, stable atmosphere) to 36 rem (solidified HAW by rail, neutral atmosphere). Consequences are highest for solidified HAW shipments because the combination of source term and release characteristics for this waste form results in the greatest amount of radioactive material being released under both moderate and extreme severity accident conditions.

Since issuance of the Draft EIS, more recent estimates of the radionuclide inventory in the waste forms produced under the waste processing alternatives have become available. DOE compared the cargo-related accident impacts calculated using the more recent radionuclide inventory with those published in the Draft EIS. DOE concluded that the transportation analysis in this EIS would not be substantially different from an analysis performed with the more recent radionuclide inventory.

Table C.5-12. Moderate severity truck and rail accident critical receptor consequences for all waste forms under neutral and stable atmospheric conditions.

Waste form shipped	Truck					Rail				
	Source[a] (curies)	TEDE[b] (rem) Neutral	LCF probability	TEDE[b] (rem) Stable	LCF probability	Source[a] (curies)	TEDE[b] (rem) Neutral	LCF probability	TEDE[b] (rem) Stable	LCF probability
Class A ***Type*** grout	7.9×10^{-5}	2.4×10^{-5}	1.2×10^{-8}	3.8×10^{-7}	1.9×10^{-10}	2.0×10^{-4}	4.6×10^{-5}	2.3×10^{-8}	9.1×10^{-7}	4.6×10^{-10}
Vitrified ***HLW (at INEEL)***	2.9×10^{-4}	5.8×10^{-5}	2.9×10^{-8}	1.4×10^{-6}	7.0×10^{-10}	5.8×10^{-4}	1.2×10^{-4}	6.2×10^{-8}	2.8×10^{-6}	1.4×10^{-9}
Solidified HAW	0.89	0.18	9.0×10^{-5}	4.3×10^{-3}	2.2×10^{-6}	1.8	0.36	1.8×10^{-4}	8.7×10^{-3}	4.4×10^{-6}
Vitrified ***HLW (at Hanford)***	7.4×10^{-5}	2.2×10^{-5}	1.1×10^{-8}	3.4×10^{-7}	1.7×10^{-10}	1.5×10^{-4}	3.5×10^{-5}	1.8×10^{-8}	6.7×10^{-7}	3.3×10^{-10}
HIP HLW	5.1×10^{-5}	1.6×10^{-5}	8.0×10^{-9}	2.1×10^{-7}	1.1×10^{-10}	1.0×10^{-4}	2.4×10^{-5}	1.2×10^{-8}	4.0×10^{-7}	2.0×10^{-10}
Cementitious HLW	0.058	8.8×10^{-3}	4.4×10^{-6}	2.1×10^{-4}	1.1×10^{-7}	0.11	0.018	9.0×10^{-6}	4.3×10^{-4}	2.2×10^{-7}
Early Vitrified HLW	2.4×10^{-5}	1.3×10^{-5}	6.5×10^{-9}	1.1×10^{-7}	5.3×10^{-11}	6.1×10^{-5}	1.8×10^{-5}	9.2×10^{-9}	2.4×10^{-7}	1.2×10^{-10}
Calcine ***(to Hanford)***	0.55	0.085	4.3×10^{-5}	2.1×10^{-3}	1.1×10^{-6}	1.1	0.17	8.5×10^{-5}	4.1×10^{-3}	2.1×10^{-6}
CsIX Resin	1.9	9.8×10^{-3}	4.9×10^{-6}	2.4×10^{-4}	1.2×10^{-7}	1.9	9.7×10^{-3}	4.9×10^{-6}	2.3×10^{-4}	1.2×10^{-7}
Vitrified ***LLW fraction (at Hanford)***	1.8×10^{-6}	1.1×10^{-5}	5.5×10^{-9}	4.8×10^{-8}	2.4×10^{-11}	3.0×10^{-6}	1.2×10^{-5}	6.0×10^{-9}	6.7×10^{-8}	3.4×10^{-11}
Class C ***Type*** grout	0.048	2.3×10^{-3}	1.2×10^{-6}	5.4×10^{-5}	2.7×10^{-8}	0.15	6.7×10^{-3}	3.4×10^{-6}	1.6×10^{-4}	8.0×10^{-8}
Early Vitrified RH-TRU	4.4×10^{-6}	8.3×10^{-6}	4.2×10^{-9}	3.5×10^{-8}	1.8×10^{-11}	8.7×10^{-6}	9.1×10^{-6}	4.6×10^{-9}	5.6×10^{-8}	2.8×10^{-11}
Grouted CH-TRU	3.3×10^{-7}	7.7×10^{-6}	3.9×10^{-9}	2.6×10^{-8}	1.3×10^{-11}	6.7×10^{-7}	8.2×10^{-6}	4.1×10^{-9}	3.8×10^{-8}	1.9×10^{-11}
RH-TRU ***Fractions***	4.0×10^{-6}	6.1×10^{-5}	3.1×10^{-8}	1.3×10^{-6}	6.5×10^{-10}	8.0×10^{-6}	1.2×10^{-4}	6.0×10^{-8}	2.6×10^{-6}	1.3×10^{-9}
Vitrified calcine (separated)	3.5×10^{-4}	7.7×10^{-5}	3.8×10^{-8}	1.7×10^{-6}	8.3×10^{-10}	7.1×10^{-4}	1.5×10^{-4}	7.3×10^{-8}	3.3×10^{-6}	1.7×10^{-9}
Vitrified calcine	2.4×10^{-5}	1.3×10^{-5}	6.5×10^{-9}	1.1×10^{-7}	5.3×10^{-11}	6.1×10^{-5}	1.8×10^{-5}	9.2×10^{-9}	2.4×10^{-7}	1.2×10^{-10}
Vitrified SBW	6.5×10^{-6}	9.5×10^{-6}	4.8×10^{-9}	4.7×10^{-8}	2.3×10^{-11}	1.3×10^{-5}	1.1×10^{-5}	5.4×10^{-9}	7.7×10^{-8}	3.9×10^{-11}
NGLW grout	6.5×10^{-7}	7.7×10^{-6}	3.9×10^{-9}	2.2×10^{-8}	1.1×10^{-11}	5.2×10^{-7}	7.7×10^{-6}	3.8×10^{-9}	2.1×10^{-8}	1.0×10^{-11}
RH-TRU Solids	5.5×10^{-6}	9.8×10^{-6}	4.9×10^{-9}	7.3×10^{-8}	3.7×10^{-11}	1.1×10^{-5}	1.2×10^{-5}	6.1×10^{-9}	1.3×10^{-7}	6.6×10^{-11}
Calcine (to NGR)	4.8×10^{-5}	1.5×10^{-5}	7.3×10^{-9}	1.9×10^{-7}	9.7×10^{-11}	9.6×10^{-5}	2.3×10^{-5}	1.1×10^{-8}	3.7×10^{-7}	1.9×10^{-10}
Steam Reformed SBW	1.8×10^{-6}	7.9×10^{-6}	3.9×10^{-9}	2.6×10^{-8}	1.3×10^{-11}	1.4×10^{-6}	7.7×10^{-6}	3.9×10^{-9}	2.2×10^{-8}	1.1×10^{-11}

a. Amount of radioactive material dispersed during the accident.

b. Total effective dose equivalent committed to an adult located 0.1 (neutral) and 0.6 (stable) kilometers downwind from the accident site for a two-hour exposure period.

CsIX = cesium ion exchange; HAW = high-activity waste; LCF = latent cancer fatality; NGLW = newly generated liquid waste; ***NGR = national geologic repository*** .

Table C.5-13. Extreme severity truck and rail accident critical receptor consequences for all waste forms under neutral and stable atmospheric conditions.

Waste form shipped	Truck					Rail				
	Source[a] (curies)	TEDE[b] (rem) neutral	LCF probability	TEDE[b] (rem) stable	LCF probability	Source[a] (curies)	TEDE[b] (rem) neutral	LCF probability	TEDE[b] (rem) stable	LCF probability
Class A ***Type*** grout	7.9×10^{-3}	1.5×10^{-3}	7.5×10^{-7}	3.7×10^{-5}	1.9×10^{-8}	0.020	3.8×10^{-3}	1.9×10^{-6}	9.0×10^{-5}	4.5×10^{-8}
Vitrified ***HLW (at INEEL)***	0.17	0.033	1.6×10^{-5}	7.9×10^{-4}	3.9×10^{-7}	0.33	0.066	3.3×10^{-5}	1.6×10^{-3}	8.0×10^{-7}
Solidified HAW	89	1.8	9.0×10^{-3}	0.43	2.2×10^{-4}	180	***36***	1.8×10^{-2}	0.87	4.4×10^{-4}
Vitrified ***HLW (at Hanford)***	***0.042***	7.7×10^{-3}	3.9×10^{-6}	1.9×10^{-4}	9.3×10^{-8}	***0.084***	***0.015***	7.7×10^{-6}	3.7×10^{-4}	1.9×10^{-7}
HIP HLW	0.029	4.5×10^{-3}	2.3×10^{-6}	1.1×10^{-4}	5.5×10^{-8}	0.058	9.0×10^{-3}	4.5×10^{-6}	2.2×10^{-4}	1.1×10^{-7}
Cementitious HLW	5.8	0.88	4.4×10^{-4}	0.021	1.1×10^{-5}	11	1.8	9.0×10^{-4}	0.043	2.2×10^{-5}
Early Vitrified HLW	0.014	2.1×10^{-3}	1.1×10^{-6}	5.1×10^{-5}	2.5×10^{-8}	0.035	5.2×10^{-3}	2.6×10^{-6}	1.3×10^{-4}	6.5×10^{-8}
Calcine ***(to Hanford)***	55	8.5	4.3×10^{-3}	0.21	1.1×10^{-4}	110	17	8.5×10^{-3}	0.41	2.1×10^{-4}
CsIX Resin	190	0.98	4.9×10^{-4}	0.024	1.2×10^{-5}	380	1.9	9.5×10^{-4}	0.047	2.4×10^{-5}
Vitrified ***LLW fraction (at Hanford)***	1.0×10^{-3}	7.0×10^{-4}	3.5×10^{-7}	1.6×10^{-5}	8.0×10^{-9}	1.7×10^{-3}	1.2×10^{-3}	6.0×10^{-7}	2.7×10^{-5}	1.4×10^{-8}
Class C ***Type*** grout	4.8	0.23	1.2×10^{-4}	5.4×10^{-3}	2.7×10^{-6}	15	0.67	3.4×10^{-4}	0.016	8.0×10^{-6}
Early Vitrified RH-TRU	2.5×10^{-3}	5.1×10^{-4}	2.6×10^{-7}	1.2×10^{-5}	6.0×10^{-9}	5.0×10^{-3}	1.0×10^{-3}	5.0×10^{-7}	2.4×10^{-5}	1.2×10^{-8}
Grouted CH-TRU	8.3×10^{-3}	0.013	6.5×10^{-6}	3.1×10^{-4}	1.6×10^{-7}	0.017	0.026	1.3×10^{-5}	6.2×10^{-4}	3.1×10^{-7}
RH-TRU ***Fractions***	0.13	1.8	9.0×10^{-4}	0.043	2.2×10^{-5}	0.27	3.6	1.8×10^{-3}	0.086	4.3×10^{-5}
Vitrified calcine (separated)	***0.20***	***0.039***	2.0×10^{-5}	9.4×10^{-4}	4.7×10^{-7}	***0.40***	***0.078***	3.9×10^{-5}	1.9×10^{-3}	9.4×10^{-7}
Vitrified calcine	***0.014***	2.1×10^{-3}	1.1×10^{-6}	5.1×10^{-5}	2.5×10^{-8}	***0.035***	5.2×10^{-3}	2.6×10^{-6}	1.3×10^{-4}	6.3×10^{-8}
Vitrified SBW	3.7×10^{-3}	7.4×10^{-4}	3.7×10^{-7}	1.8×10^{-5}	8.8×10^{-9}	7.4×10^{-3}	1.5×10^{-3}	7.3×10^{-7}	3.5×10^{-5}	1.8×10^{-8}
NGLW grout	3.7×10^{-4}	2.0×10^{-4}	1.0×10^{-7}	4.8×10^{-6}	2.4×10^{-9}	3.0×10^{-4}	1.6×10^{-4}	8.2×10^{-8}	3.8×10^{-6}	1.9×10^{-9}
RH-TRU Solids	***0.18***	***0.082***	4.1×10^{-5}	2.0×10^{-3}	9.8×10^{-7}	***0.37***	***0.16***	8.2×10^{-5}	3.9×10^{-3}	2.0×10^{-6}
Calcine (to NGR)	***0.027***	4.2×10^{-3}	2.1×10^{-6}	1.0×10^{-4}	5.1×10^{-8}	***0.055***	8.4×10^{-3}	4.2×10^{-6}	2.0×10^{-4}	1.0×10^{-7}
Steam Reformed SBW	1.0×10^{-3}	2.8×10^{-4}	1.4×10^{-7}	6.6×10^{-6}	3.3×10^{-9}	8.1×10^{-4}	2.1×10^{-4}	1.0×10^{-7}	4.8×10^{-6}	2.4×10^{-9}

a. Amount of radioactive material dispersed during the accident.

b. Total effective dose equivalent committed to an adult located 0.1 (neutral) and 0.6 (stable) kilometers downwind from the accident site for a two-hour exposure period.

CsIX = cesium ion exchange; HAW = high-activity waste; LCF = latent cancer fatality; ***NGR = national geologic repository*** .

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