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TRANSPORTATION

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"The safety record associated with the current regulatory system for the transportation of spent fuel is exemplary – approximately 1,300 shipments of civilian fuel and 920,000 miles without an accidental release"

Chairman Meserve
May 10, 2002

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Introduction

- Safety in transportation of radioactive materials is maintained based on a combination of factors
  - Physical properties of material
  - Providing sufficient containment, shielding, and criticality control through the use of certified packaging
  - Comprehensive regulations including operational requirements for shippers, carriers, packages and vehicles
- Understanding the regulatory framework is an important aspect of conducting a realistic assessment of potential radiological hazards, consequences, and risks associated with transportation

Regulatory Framework

- NRC and DOT share regulatory responsibilities for transportation of radioactive materials (memorandum of understanding)
  - DOT certifies packages for quantities of radioactive materials not exceeding Type A limits and for Low Specific Activity materials
  - NRC certifies packages for quantities of material in excess of Type A limits (Type B) and fissile material
  - Collaboration on development of safety standards with specific roles consistent with each agencies jurisdiction

Nuclear Regulatory Commission

- 10 CFR Part 71
  - package certification requirements
  - package activity limits
  - external radiation limits for packages
  - accident/incident investigations
  - DOT transport regulations incorporated by reference
  - inspections
- 10 CFR Part 73 -- Physical protection
- 10 CFR 63.21 -- License application includes an environmental impact statement

U.S. Department of Transportation

- Requirements for transportation of hazardous material (including radioactive materials)
- Designated "competent authority" before IAEA
- Certification of international shipments
- 49 CFR 170 through 189:
  - Requirements for shippers and carriers (radiological controls, communications, training, routing)

International Atomic Energy Agency

- Publishes consensus-based international regulations for safe transportation of radioactive materials
- Both NRC and DOT regulations are consistent with IAEA regulations

Department of Energy

- Required by Atomic Energy Act to use NRC certified packages for shipments to repository
- Has authority to impose its own security requirements for shipments to repository
- Completed Final Environmental Impact Statement in 2002 (includes assessment of transportation risks)
  - Supplement pending

Basic Concepts

Modes of Transportation for Spent Fuel

- Truck
  - Highway Route Controlled Quantity Routing
- Rail
  - No special routing requirements
- Barge/Ship
  - Navigatable waterways (check)
- DOE Expects Combination of Truck and Rail for Shipments to Yucca Mountain

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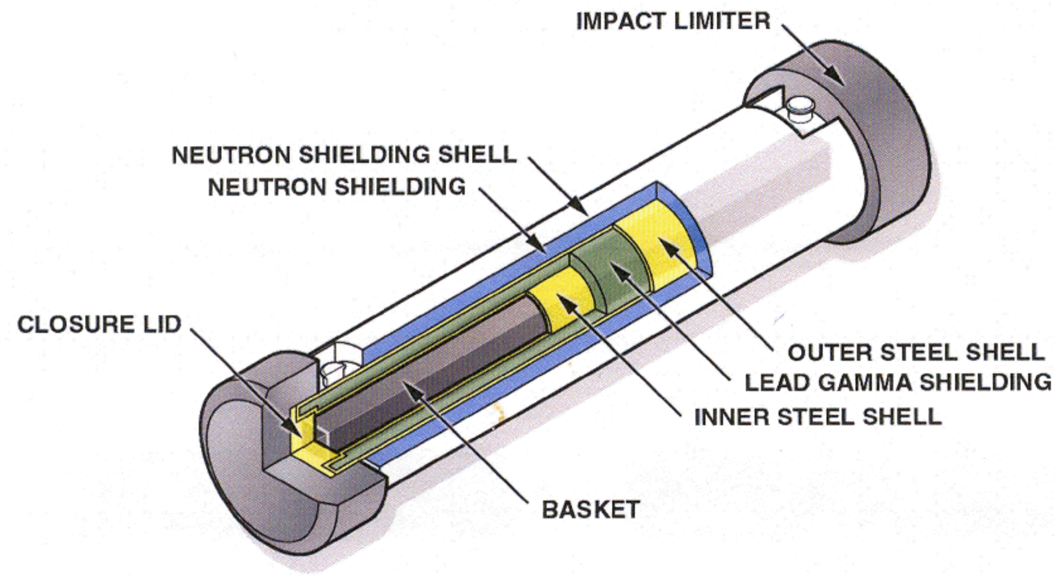
Transportation Packaging

TYPICAL SPENT FUEL TRANSPORTATION CASK



Generic Truck Cask for Spent Fuel

<u>Typical Specifications</u>
Gross Weight (including fuel): 50,000 pounds (25 tons)
Cask Diameter: 4 feet
Overall Diameter (including Impact Limiters): 6 feet
Overall Length (including Impact Limiters): 20 feet
Capacity: Up to 4 PWR or 9 BWR fuel assemblies

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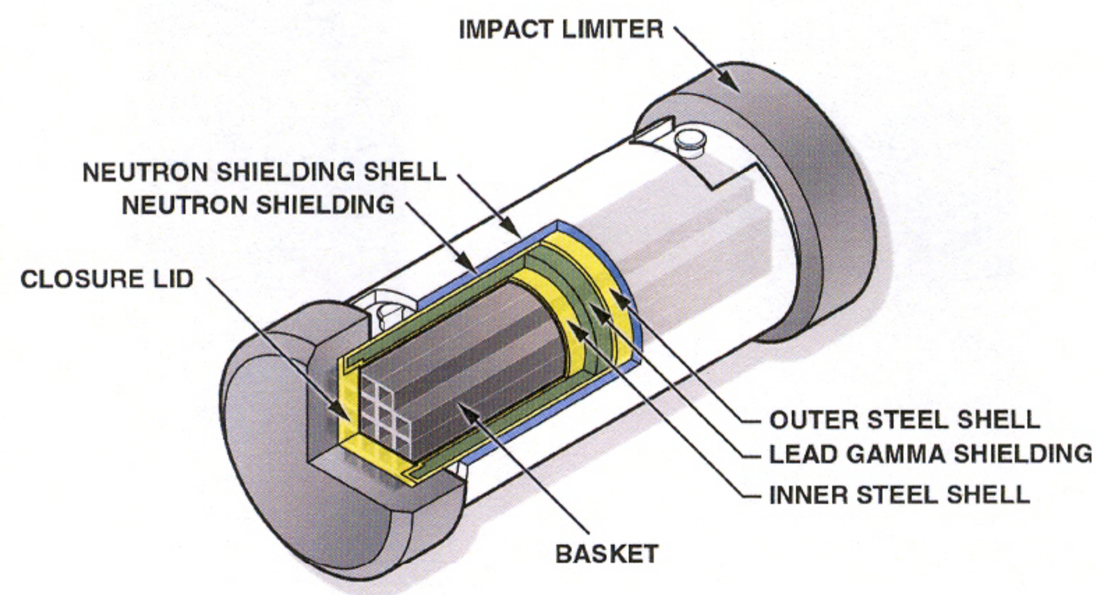
Transportation Packaging



Generic Rail Cask for Spent Fuel

<u>Typical Specifications</u>
Gross Weight (including fuel): 250,000 pounds (125 tons)
Cask Diameter: 8 feet
Overall Diameter (including Impact Limiters): 11 feet
Overall Length (including Impact Limiters): 25 feet
Capacity: Up to 26 PWR or 61 BWR fuel assemblies

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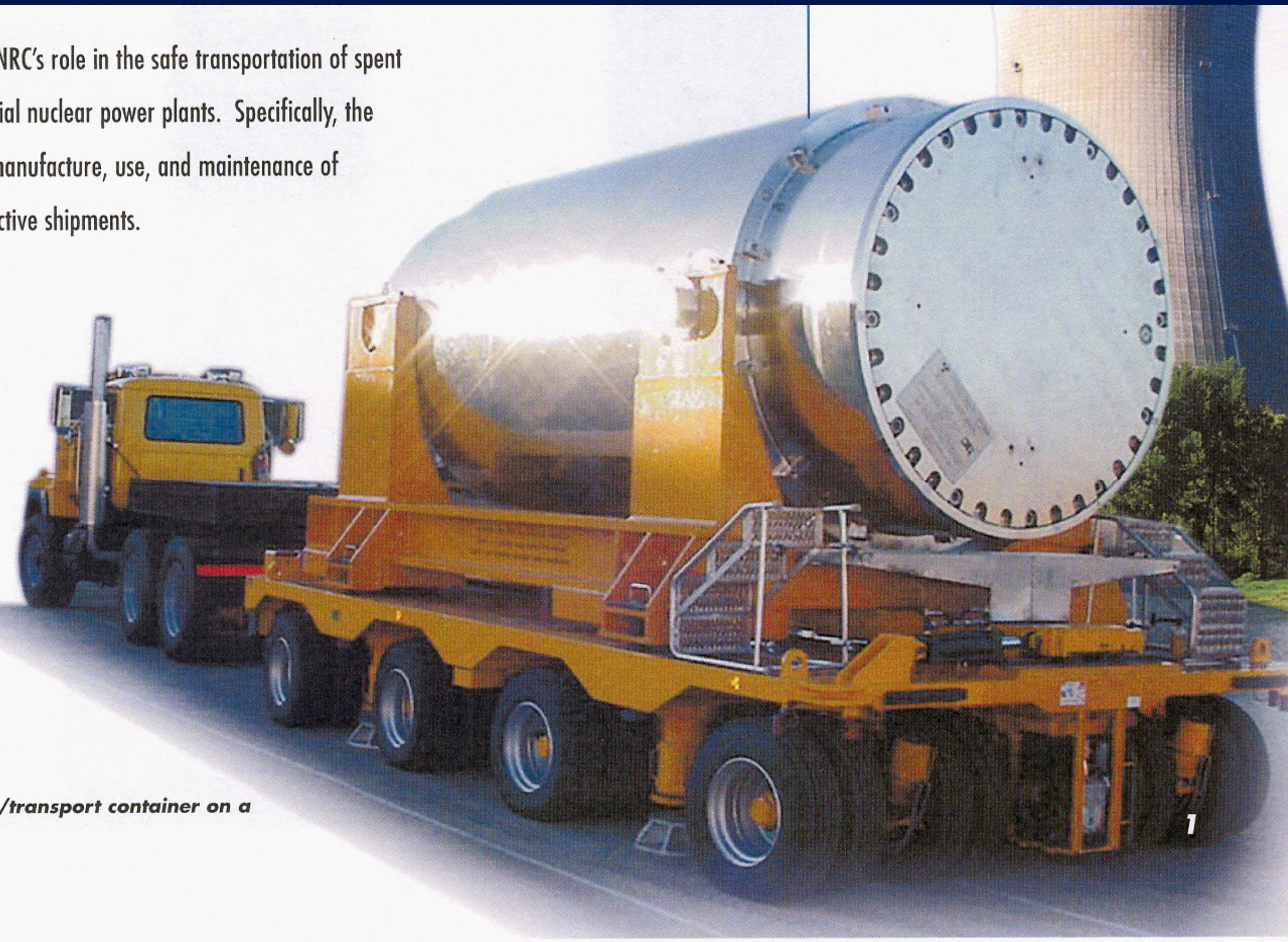
Transportation Packaging

This booklet relates to the NRC's role in the safe transportation of spent nuclear fuel from commercial nuclear power plants. Specifically, the NRC oversees the design, manufacture, use, and maintenance of containers for these radioactive shipments.



This is an empty storage/transport container on a semi tractor-trailer rig.

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Transportation Radiological Hazards

- Direct radiation from packaged waste (“incident free” dose)
  - public (on-link, off-link, stops)
  - workers (crew, stops, loading/unloading)
  - dose received any time package is in vicinity of persons
- Radiation exposure from loss of shielding or accidental release of radioactive contents (“accident” conditions)
  - Direct radiation, inhalation, and/or ingestion doses
  - Includes transport vehicle accidents, criticality

Application of Health Physics-Based Principles in Transportation Requirements

- Transport Index
- External radiation limits
- Containment
- Criticality Control
- Routing
- Separation
- Shielding
- Labeling and Marking

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Estimating Dose, Risk, and Health Effects

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Transportation Risk Assessment Codes

- RADTRAN 5
  - Calculates radiological consequences and risks from incident-free and accident transportation conditions
  - Probabilistic treatment of accident risks
  - Truck, Rail, Barge, Ship modes considered
- RISKIND 2.0
  - Similar to RADTRAN
  - Optimized for calculating scenario-specific consequences and risk
  - Truck and Rail only

Incident Free Dose Calculations

(RADTRAN 5)

- Dose to specific populations in vicinity of package during transport is computed as a function of:
  - Package dose rate
  - Exposure time
  - Distance from package
  - Shielding effectiveness (where applicable)
  - Population densities

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Package Dose Rate: Gamma Radiation

- Based on calculation of gamma dose rate as a function of distance r from a point source of radiation (i.e., the package)

$$DR_G(r)=Q\cdot \frac{k_0}{r^2}\cdot DR_p\cdot FG$$

where:

Q = unit conversion

k_0 = point-source shape factor = $(1+0.5d_e)^2$

d_e = effective package or conveyance dimension (m)

Dr_p = package or vehicle dose rate at 1m (mrem/hr)

FG = fraction of package or vehicle dose rate that is gamma radiation

- For stops and handling calculations, a line source is used for large packages at close distance ($<= 2\ d_e$)

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Package Dose Rate: Neutron Radiation

- Based on calculation of neutron dose rate as a function of distance r from a point source of radiation (i.e., the package)

$$DR_N(r)=Q\cdot DR_p\cdot FN\cdot k_0\cdot \exp(-\mu r)\cdot\frac{(1+a_1r+a_2r^2+a_3r^3+a_4r^4)}{r^2}$$

where:

Q = unit conversion
Dr_p = package or vehicle dose rate at 1m (mrem/hr)
FN = fraction of package or vehicle dose rate that is neutron radiation
k_0 = point-source shape factor = $(1+0.5d_e)^2$ (m^2)
d_e = effective package or conveyance dimension (m)

- For stops and handling calculations, a line source is used for large packages at close distance (<= 2 d_e)

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Exposure Times

- Based on the characteristics of the population and conveyance
  - On-link public (two way traffic, both directions, for rail applicable to trains moving in opposite direction)
  - Off-link public (vehicle velocity provides time)
  - Crew workers (length of time in transit)
  - Stops workers and public (input: stop time)
  - Loading/unloading workers (input: “handling” time)

Distances

- On-link public
  - One-way traffic (inputs: following distance, lane width)
  - Two-way traffic (input: opposing lane separation distance)
- Off-link public
  - Inputs: min/max distances to roadside populations
- Crew workers
  - Inputs: mode-specific source to crew distances
- Stops workers and public
  - Inputs: mode-specific average exposure distance at stops
- Loading/unloading workers
  - Inputs: package-specific average handler distances

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Shielding Effectiveness

- Pedestrians (no shielding)
- Off-link buildings
  - Option 1 – all construction assumed 100% effective shielding
  - Option 2 – more realistic scenario Rural (none), Suburban (moderate), Urban (heavy)
  - Option 3 – no shielding assumed for Rural, Suburban, Urban areas (most conservative)
- Stops population shielding factor
- Crew shielding factor for truck and ship modes
  - Rail crew shielding is 100% effective (massive engine, distance)

Population Densities

- Route is partitioned into segments with unique population densities
  - Rural
  - Suburban
  - Urban
- User inputs for numbers of crew, handlers, pedestrians, and people at stops
- As route distance increases, the number of people exposed increases

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Example Incident Free Calculation

RADTRAN 5

- Population dose to public living adjacent to truck route (i.e., "Offlink")

$$Dose = \frac{Q \cdot 4 \cdot k_0 \cdot Dr_v \cdot PD \cdot NSH_L \cdot DIST_L}{V} \cdot \int_{min}^{max} I(x)dx$$

where:

Q	= Unit conversion
k_0	= Point source package shape factor
Dr_v	= Conveyance dose rate at 1m from surface (mrem/hr)
$PD_{r,s,u}$	= Population density (persons/km^2) for rural, suburban, or urban link
NSH_L	= Number of shipments on link L
$DIST_L$	= Distance traveled on link L
max	= Maximum distance to population perpendicular to route (m)
min	= Minimum distance to population perpendicular to route (m)
$I(x)$	= Integration of dose rate attenuation and buildup function over distance interval

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Accident Dose Calculations

- Accident consequences estimated based on accident severity categories
  - Low severity = low impact = loss of shielding only
  - Increasing severity = increasing release fractions (inputs)
- Loss of shielding
  - Dose rate is based on modified point source equation similar to incident free (e.g., dose rate, time, distance)
- Radioactive material releases
  - Airborne dispersion/deposition based on Gaussian “puff” model
  - Pathways include cloudshine, plume inhalation, groundshine, inhalation of resuspended material, and local food ingestion

Accident Dose Calculations

- Probability of accidents specified for each severity level
  - Probability is inversely proportional to severity (e.g., severe damage producing accident probability is low)
- Risk is called "Dose-Risk"

$$\Sigma_n(\text{accident dose}_{sev1...n} \times \text{probability}_{sev1...n})$$

- Individual and population doses
- Health effects

(Person-rem dose) x (cancer risk per person-rem)

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Inhalation Calculation

Dose to Individual

$$\text{Dose} = \Sigma_i \Sigma_o (Ci_i \times PPS \times RF_{i,j} \times AER_{i,j} \times RESP_{i,j} \times RPC_{i,o} \times X_n \times BR)$$

where:

- Ci_i = Curies of isotope *i* in package
- PPS = number of packages per shipment
- $RF_{i,j}$ = fraction of package contents released in accident of severity *j*
- $AER_{i,j}$ = fraction of released material that is in aerosol form in accident of severity *j*
- $RESP_i$ = fraction of aerosol material that is respirable in accident of severity *j*
- $RPC_{i,o}$ = inhalation dose coefficient (rem/Ci inhaled) for *i*th isotope and *o*th organ (lung, marrow, thyroid)
- X_n = dilution factor (chi) in *n*th isopleth area (Ci-sec/m^3 per Ci released)
- BR = breathing rate (m^3/sec)

- Inhalation dose to <u>population</u> is similar but includes area integrated X_n and additional terms for dispersion area and population density

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Groundshine Calculation

Dose to Individual

Dose=

$$\sum_i [GDF_i \times Ci_{i,} \times PPS \times (RF_{i,j} \times AER_{i,j}) \times (V_d \times X_n) \times 1.0E{+}6\mu Ci/Ci]$$

where:

GDF_i	= Groundshine dose coefficient for isotope *i* (rem-m2/µCi-day)
Ci_i	= Curies of isotope *i* in package
PPS	= number of packages per shipment
$RF_{i,j}$	= fraction of package contents released in accident of severity *j*
$AER_{i,j}$	= fraction of released material that is in aerosol form in accident of severity *j*
Vd	= Deposition velocity for plume of aerosol form material
X_n	= dilution factor (chi) in *n*th isopleth area (Ci-sec/m^3 per Ci released)

- Decay and weathering loss rates are accounted for but not shown
- Variants of computation for pre-interdiction and post-cleanup provided
- Groundshine dose to population is similar but includes population densities for each deposition area and total dose is summed for all areas

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Cloudshine Dose Calculation

Dose to Individual

$$Dose = \sum_i [CDF_i \times Ci_{i,} \times PPS \times (RF_{i,j} \times AER_{i,j}) \times X_n]$$

where:

CDF_i = Cloudshine dose coefficient for isotope *i* (rem-m^3/Ci-sec)

Ci_i = Curies of isotope *i* in package

PPS = number of packages per shipment

$RF_{i,j}$ = fraction of package contents released in accident of severity *j*

$AER_{i,j}$ = fraction of released material that is in aerosol form in accident of severity *j*

X_n = dilution factor (chi) in *n*th isopleth area (Ci-sec/m^3 per Ci released)

- Special consideration in urban accident model to account for air filtration in buildings and unique pedestrian exposure conditions
- Cloudshine dose to <u>population</u> is similar but includes plume area integrated X_n and additional term for population density

Ingestion Dose Calculation

- Computation based on COMIDA 2 Ingestion Model (also used in MACCS2 code)
- Agricultural exposure scenario
- Backyard subsistence farmer scenario
  - Family of 5 on 50,000 m^2 of land

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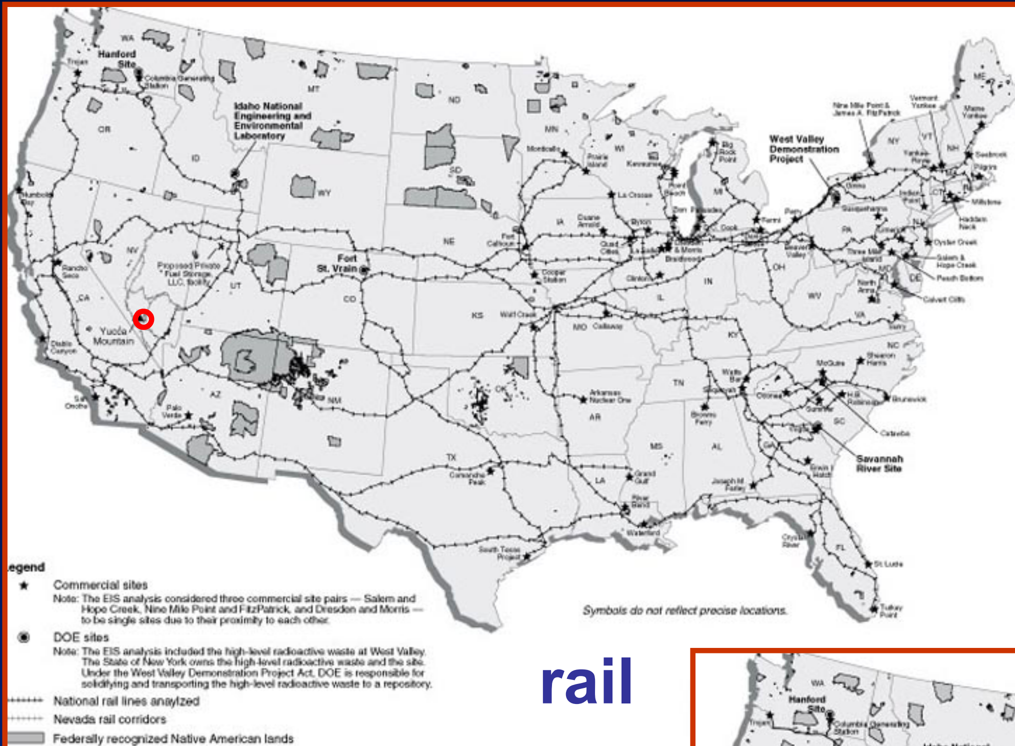
DOE Final Environmental Impact Statement (FEIS) Analyses

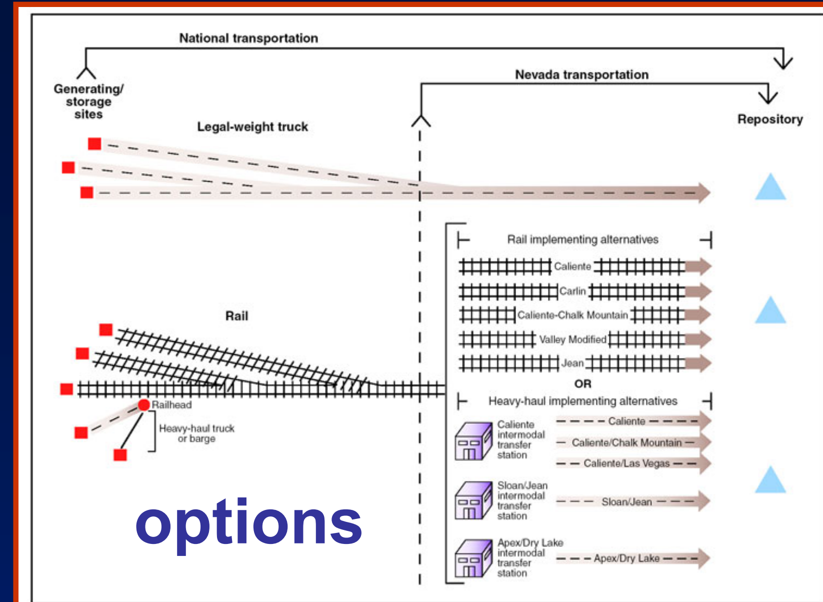
Nuclear Waste Policy Act of 1982 (as amended)

- "*Any recommendation made by the Secretary under this section shall be considered a major Federal action significantly affecting the quality of the human environment for purposes of the National Environmental Policy Act of 1969*"
- Environmental Impact Statement (EIS) is required
- EIS must assess all reasonably foreseeable impacts
- Transportation impacts assessed by conducting risk assessment for the DOE FEIS

Proposed Action

- High level waste shipped to Yucca Mountain from 72 commercial power reactor sites and 5 DOE sites
- Shipment by Rail and legal-weight trucks are primary modes of transport
- Rail requires supplemental transport modes
  - Legal weight truck
  - Heavy haul truck
  - Barge


Legend
Commercial sites
Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.
DOE sites
Note: The EIS analysis included the high-level radioactive waste at West Valley. The State of New York owns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste to a repository.
National rail lines analyzed
Nevada rail corridors
Federally recognized Native American lands
Symbols do not reflect precise locations.
Hanford Site
Idaho National Engineering and Environmental Laboratory
West Valley Demonstration Project
Fort St. Vrain
Yucca Mountain
Savannah River Site
rail


National transportation
Nevada transportation
Generating/ storage sites
Repository
Legal-weight truck
Rail
Railhead
Heavy-haul truck or barge
Rail implementing alternatives
Caliente
Carlin
Caliente-Chalk Mountain
Valley Modified
Jean
OR
Heavy-haul implementing alternatives
Caliente intermodal transfer station
Caliente
Caliente/Chalk Mountain
Caliente/Las Vegas
Sloan/Jean intermodal transfer station
Sloan/Jean
Apex/Dry Lake intermodal transfer station
Apex/Dry Lake
options


Legend
Commercial sites
Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.
DOE sites
Note: The EIS analysis included the high-level radioactive waste at West Valley. The State of New York owns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste to a repository.
National highways analyzed
Federally recognized Native American lands
Symbols do not reflect precise locations.
These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. States or tribes can designate alternative preferred routes (40 CFR 397.103).
Hanford Site
Idaho National Engineering and Environmental Laboratory
West Valley Demonstration Project
Fort St. Vrain
Yucca Mountain
Savannah River Site
highway

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Categories of Waste Considered

- Commercial Spent Nuclear Fuel
- DOE Spent Nuclear Fuel
- Naval Spent Nuclear Fuel
- High Level Waste
- Commercial Greater-than-Class-C Waste
- DOE Special-Performance-Assessment-Required Low-Level Radioactive Waste

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Transportation Codes Used

- CALVIN – used to estimate number of shipments of spent fuel from commercial sites
- HIGHWAY – used to select highway routes
- INTERLINE – used to select rail lines
- RADTRAN 5 – incident-free and accident transportation consequences and risks
- RISKIND – incident-free and accident maximally exposed individual calculations

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Assessment Methods

- Use modeling as basis for comparison of relative risks of routing options
  - National transportation from reactor/other sites to Nevada (mostly rail and legal truck)
  - Comparison of 3 options for Nevada shipments to proposed repository (legal truck, rail spur, heavy haul alternative routing options)

Assessment Methods

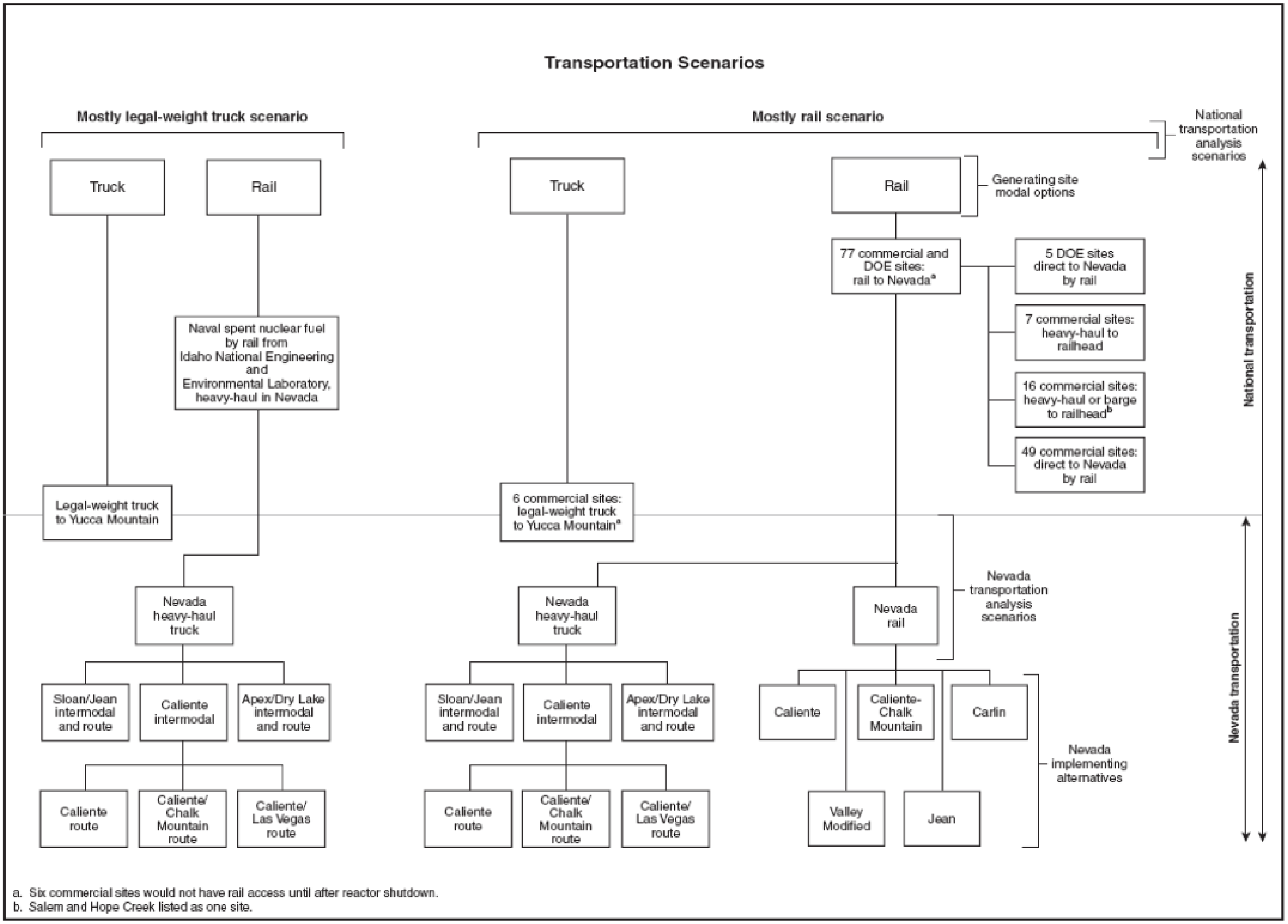

Figure 6-2. Relationship between transportation modes, national and Nevada analytical scenarios, and Nevada transportation implementing alternatives.

Assessment Methods

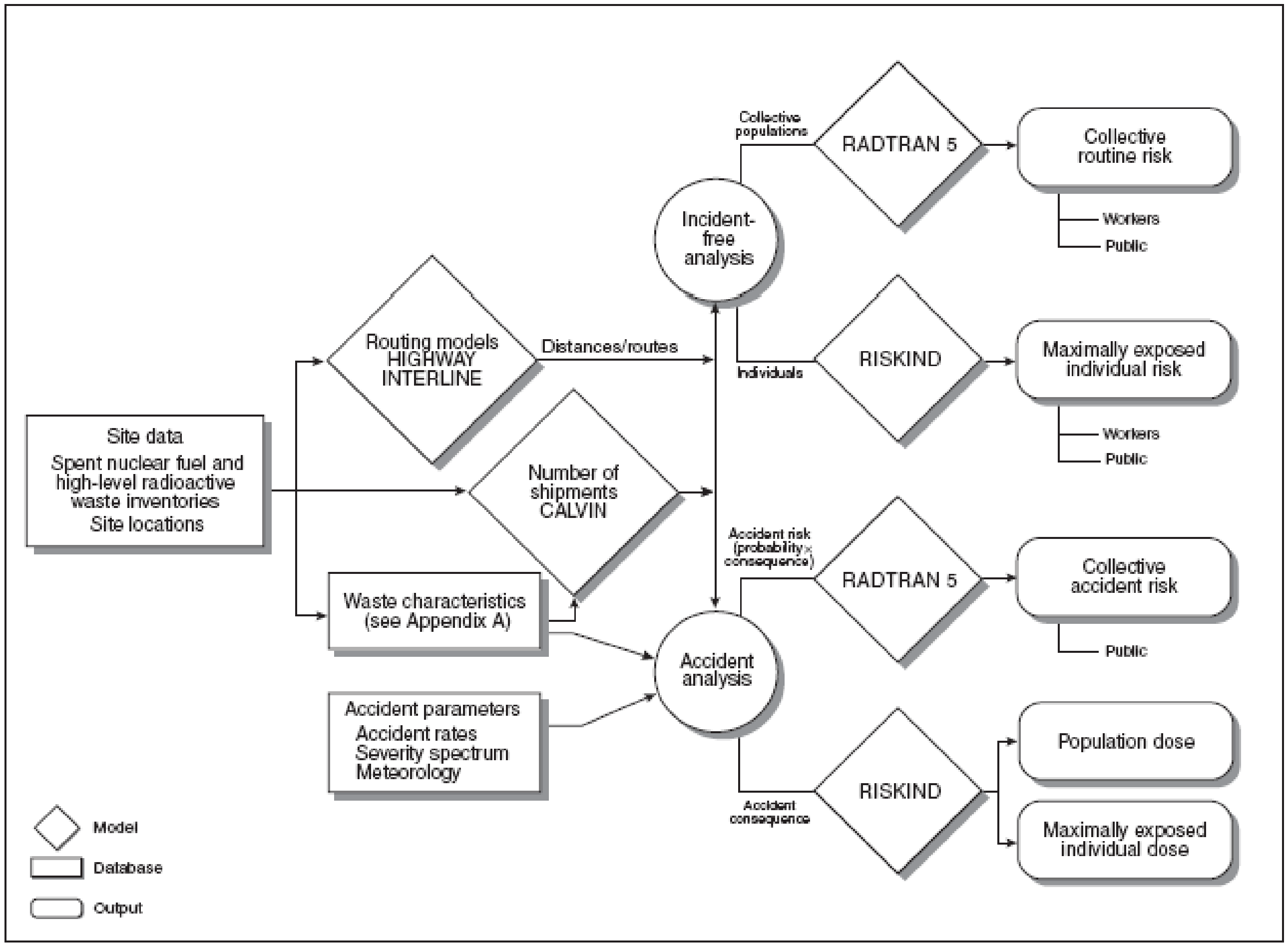

Figure J-1. Methods and approach for analyzing transportation radiological health risk.

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Assumptions

- No public dose from loading or unloading operations
- No specific routes have been proposed, routes used for analysis are assumed representative of future route conditions
- Spent fuel characteristics expected to be representative of average hazard potential for all spent fuel used
- Stop time for trucks is 1 hour for every 10 hours of travel
- Loading operations similar to current commercial operations
- Dose rate for package set to 10 mrem/hr at 2m
  - maximum allowed by DOT regulations
  - equates to <0.2 mrem/hr at 30 m and <0.0002 mrem at 800m
- Public dose to in tact package prior to emergency response arrival is modeled in accident calculations

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Inputs: Number of Shipments

Table J-1. Summary of estimated number of shipments for the various inventory and national transportation analysis scenario combinations.

	Mostly truck		Mostly rail	
	Truck	Rail	Truck	Rail
Proposed Action				
Commercial spent nuclear fuel	41,001	0	1,079	7,218
High-level radioactive waste	8,315	0	0	1,663
DOE spent nuclear fuel	3,470	300	0	765
Greater-Than-Class-C waste	0	0	0	0
Special-Performance-Assessment-Required waste	0	0	0	0
Proposed Action totals	*52,786*	*300*	*1,079*	*9,646*
Module 1[a]				
Commercial spent nuclear fuel	79,684	0	3,122	12,989
High-level radioactive waste	22,280	0	0	4,458
DOE spent nuclear fuel	3,721	300	0	796
Greater-Than-Class-C waste	0	0	0	0
Special-Performance-Assessment-Required waste	0	0	0	0
Module 1 totals	*105,685*	*300*	*3,122*	*18,243*
Module 2[a]				
Commercial spent nuclear fuel	79,684	0	3,122	12,989
High-level radioactive waste	22,280	0	0	4,458
DOE spent nuclear fuel	3,721	300	0	796
Greater-Than-Class-C waste	1,096	0	0	282
Special-Performance-Assessment-Required waste	1,763	55	0	410
Module 2 totals	*108,544*	*355*	*3,122*	*18,935*

a. The number of shipments for Module 1 includes all shipments of spent nuclear fuel and high-level radioactive waste included in the Proposed Action and shipments of additional spent nuclear fuel and high-level radioactive waste as described in Appendix A. The number of shipments for Module 2 includes all the shipments in Module 1 and additional shipments of highly radioactive materials described in Appendix A.

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Inputs: National Incident-Free Analysis

Table J-15. Input parameters and parameter values used for the incident-free national truck and rail transportation analysis, except stops.

Parameter	Legal-weight truck transportation	Rail transportation	Legal-weight truck and rail
Package type			Type B shipping cask
Package dimension	5.2 meters[a] long 1.0 meters diameter	5.06 meters long 2.0 meters diameter	
Dose rate			10 millirem per hour, 2 meters from side of vehicle[f]
Number of crewmen	2	5	
Distance from source to crew	3.1 meters[a]	152 meters[b]	
Speed			
Rural	88 km[c,d] per hour	64 km per hour	
Suburban	88 km/hr non-rush hour 44 km/hr rush hour	40 km per hour	
Urban	88 km/hr non-rush hour 44 km/hr rush hour	24 km per hour	
Input for stop doses: see Table J-17			
Number of people per vehicle sharing route	2	3	
Minimum and maximum distances to exposed population			30 meters to 800 meters
Population densities (persons per km²)[d]			
Rural			(e)
Suburban			(e)
Urban			(e)
One-way traffic count (vehicles per hour)			
Rural	470	1	
Suburban	780	5	
Urban	2,800	5	

a. To convert meters to feet, multiply by 3.2808.
b. Rail crew in transit would be too far and too well shielded from the external cask radiation to receive any dose. This number is not used in the calculation and is provided for information only.
c. To convert kilometers to miles, multiply by 0.62137.
d. Assumes general freight rather than dedicated service.
e. Population densities along transportation routes were estimated using the HIGHWAY and INTERLINE computer programs, then were extrapolated to 2035.
f. The actual (equivalent) input to RADTRAN 5 is 14 millirem per hour at 1 meter (3.3 feet) from the side of the vehicle.

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Inputs: Stop Dose Parameters

Table J-17. Input parameter values for stop doses for routine incident-free transportation.

Stop type	Population exposed	Minimum distance (meters)[a]	Maximum distance (meters)[a]	Stop time	Other
		Doses to the public			
People at truck stops	6.9[b]	1[b]	15.8[b]	20 min[b]	845 km[c] between stops
Residents near truck stops	Rural, suburban, or urban[d]	30	800	20 min[b]	845 km between stops
Residents near truck walkaround inspections[e]	Rural, suburban, or urban	30	800	10 min	161 km between stops
Residents near rail classification stops	Rural, suburban, or urban	30	800	30 hr[a]	One stop at each end of trip
Residents near rail crew change stops	Rural, suburban, or urban	30	800	0.033 hr/km[b]	
		Occupational stop doses			
Truck crew dose at rest/refuel stops	2	1	15.8	20 min	845 km between stops
Truck crew dose at walkaround inspectons	1	1	1	10 min	161 km between stops
	1	Dose rate = 2 mrem/hr by regulation			
Rail crew dose at classification stops	5	(e)		30 hr	One stop at each end of trip
Rail crew dose at crew change stops	5	Calculated by multiplying the classification stop dose by 0.0018/km: a distance-dependent worker exposure factor[f]			

a. To convert meters to feet, multiply by 3.2808.
b. Derived from DIRS 152084-Griego, Smith, and Neuhauser (1996, all).
c. km = kilometer; to convert kilometers to miles, multiply by 0.62137.
d. Values used in DIRS 152476-Sprung et al. (2000, pp. 3-5 to 3-9, Table 3.3).
e. DIRS 155430-Neuhauser, Kanipe, and Weiner (2000, Appendix B) explains this calculation, which has been incorporated into RADTRAN 5.
f. DIRS 150898-Neuhauser and Kanipe (2000, pp. 51 to 52).

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Inputs: Accident Calculations

- Conditional probabilities of accidents of given severity result in 99.9% of accidents modeled lead to no release
  - Consistent with findings of NRC sponsored evaluation of transportation risks released in 2000
- Loss of sheilding accidents are included in analysis of impacts

Results: National Summary

Table 6-1. National transportation impacts for the transportation of spent nuclear fuel and high-level radioactive waste for the mostly rail and mostly legal-weight truck scenarios.[a,b]

Group	Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Worker	*Incident-free health impacts, radiological*		
	Maximally exposed individual (rem)	48[c]	48[c]
	Individual latent cancer fatality probability	0.02	0.02
	Collective dose (person-rem)	29,000	7,900 - 8,800
	Latent cancer fatality incidence	11.7	3.2 - 3.5[d]
	Industrial safety (fatalities)	0.9	0.29
Public	*Incident-free health impacts, radiological*		
	Average exposed individual (rem)	0.0005	0.0001
	Maximally exposed individual (rem)	2.4[e]	0.29
	Individual latent cancer fatality probability	0.0012	0.00014
	Collective dose (person-rem)	5,000	1,200 - 1,600
	Latent cancer fatality incidence	2.5	0.61 - 0.81
	Incident-free vehicle emissions impacts (fatalities)	0.95	0.55 - 0.77
	Radiological impacts from maximum reasonably foreseeable accident scenario		
	Frequency (per year)	2.3 in 10,000,000	2.8 in 10,000,000
	Maximally exposed individual (rem)	3	29
	Individual latent cancer fatality probability	0.0015	0.015
	Collective dose (person-rem)	1,100	9,900
	Latent cancer fatality incidence	0.55	5
	Accident dose risk (person-rem)	0.46	0.89
	Accident risk (latent cancer fatalities)	0.00023	0.00045
Public and transportation workers	*Fatalities from vehicular accidents*	4.9	2.3 - 3.1

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operation, including impacts of loading.
c. Based on 2-rem-per-year dose limit.
d. Range for the 10 rail and heavy-haul truck implementing alternatives in Nevada.
e. Based on 100-millirem-per-year dose limit.

Results: Nevada Only Summary

Table 6-4. Worker and public health and safety impacts from Nevada transportation implementing alternatives.[a]

Impact	Legal-weight truck[b]	Branch rail line: Caliente	Branch rail line: Carlin	Branch rail line: Caliente-Chalk Mountain	Branch rail line: Jean	Branch rail line: Valley Modified
Workers						
Maximally exposed individual probability of LCF[c]	0.02	0.02	0.02	0.02	0.02	0.02
Worker population LCFs	0.75	0.34	0.39	0.3	0.3	0.28
Public						
Maximally exposed individual probability of LCF	0.0016	0.00015	0.00015	0.00015	0.00015	0.00015
General population LCFs	0.17	0.009	0.019	0.009	0.08	0.013
Vehicle emissions-related health effects (fatalities)	0.09	0.25	0.25	0.2	0.23	0.13
Accident risk[d]						
Population LCFs	0.000026	0.000001	0.000001	0.000001	0.000004	0.000001
Maximum reasonably foreseeable accident scenario						
Population LCFs	0.5	5	5	5	5	5
Maximally exposed individual probability of LCF	0.0015	0.02	0.02	0.02	0.02	0.02
Traffic accident fatalities	0.49	1.93	1.85	1.57	1.27	0.94

Impact	Heavy-haul truck[b]: Caliente	Heavy-haul truck[b]: Caliente-Chalk Mountain	Heavy-haul truck[b]: Caliente/Las Vegas	Heavy-haul truck[b]: Sloan/Jean	Heavy-haul truck[b]: Apex/Dry Lake
Workers					
Maximally exposed individual probability of LCF[c]	0.02	0.02	0.02	0.02	0.02
Worker population LCFs	0.76	0.61	0.66	0.59	0.57
Public					
Maximally exposed individual probability of LCF	0.00016	0.00016	0.00016	0.00016	0.00016
General population LCFs	0.04	0.03	0.11	0.17	0.08
Vehicle emissions-related health effects (fatalities)	0.47	0.32	0.46	0.42	0.29
Accident risk[d]					
Population LCFs	0.000005	0.000001	0.000028	0.00006	0.000028
Maximum reasonably foreseeable accident scenario					
Population LCFs	5	5	5	5	5
Maximally exposed individual probability of LCF	0.02	0.02	0.02	0.02	0.02
Traffic accident fatalities	4.1	2.76	3.47	1.98	1.93

a. Impacts are totals for 24 years of operations.
b. Includes impacts to workers at an intermodal transfer station.
c. LCF = latent cancer fatality.
d. In this table, radiological accident dose risk is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. This sum is converted to latent cancer fatalities using the conversion factor of 0.0005 latent cancer fatality per person-rem.

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Summary

- Extensive regulatory framework controls many aspects of transportation and effectively maintains safety for public and workers
- Safety requirements for transportation of radioactive materials, including spent fuel, are based on established health physics principles
- FEIS applies health physics in modeling transportation impacts for YM