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Civilian Radioactive Waste Management System
Management & Operating Contractor

Environmental Baseline File for National Transportation

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June 1999

Prepared for:

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DISCLAIMER

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TABLES

ACRONYMS AND ABBREVIATIONS

DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
MTIHM	Metric tons of initial heavy metal
NRC	U.S. Nuclear Regulatory Commission

1. INTRODUCTION

This Environmental Baseline File summarizes and consolidates information related to the national-level transportation of commercial spent nuclear fuel. Topics addressed include: shipments of commercial spent nuclear fuel based on mostly truck and mostly rail shipping scenarios; transportation routing for commercial spent nuclear fuel sites and DOE sites; radionuclide inventories for various shipping container capacities; transportation routing; populations along transportation routes; urbanized area population densities; the impacts of historical, reasonably foreseeable, and general transportation; state-level food transfer factors; Federal Guidance Report No. 11 and 12 radionuclide dose conversion factors; and national average atmospheric conditions.

2. SHIPMENTS

The number of shipments from commercial nuclear facilities was estimated using the Civilian Radioactive Waste Management System Analysis and Logistics Visually Interactive model. This model estimates the number of shipments from each site based on the quantity and characteristics of spent nuclear fuel generated and stored at the site, the anticipated shipment mode (truck or rail), and shipping container capacity information. The model also takes into account regulatory limits that apply to criticality and heat generation within the shipping container. This feature results in cask derating at some sites based on the characteristics of individual spent nuclear fuel assemblies. In these cases, shipping containers are transported partially filled, primarily to meet regulatory thermal limits. In determining the number of shipments from each site, the model takes into account the order in which spent nuclear fuel is currently expected to be picked up (allocation rights) and anticipated receipt rates at the repository.

Two shipping scenarios were evaluated, one mostly rail scenario and one mostly truck scenario. The mostly rail scenario is based on using rail spent nuclear fuel shipping containers, except for those sites where a truck spent nuclear fuel shipping container must be used, due to facility constraints. The mostly truck scenario is based on using truck spent nuclear fuel shipping containers for all sites.

For each scenario, two cases were evaluated. The first case corresponds to the shipment of 63,000 metric tons of heavy metal of commercial spent nuclear fuel. The second case corresponds to the shipment of 105,000 metric tons of heavy metal of commercial spent nuclear fuel.

The shipping container capacities for the shipping scenarios are listed in Table 2-1. If the specific type of spent nuclear fuel did not meet thermal or criticality regulatory requirements, then an alternative rail shipping container with a capacity of 17 boiling water reactor or seven pressurized water reactor assemblies was used to transport the spent nuclear fuel.

The mostly truck shipping container scenario was based on a shipping container capacity of nine boiling water reactor assemblies or four pressurized water reactor assemblies. If the specific type of spent nuclear fuel did not meet thermal or criticality regulatory requirements, then the shipping container was derated. For example, the truck shipping container might only transport three pressurized water reactor assemblies instead of four pressurized water reactor assemblies if derating was required. Derated shipments are listed separately (see Table 2-1 for shipping container type notation and capacity).

Shipments are listed by facility based on the following protocol:

One Reactor, One Pool - facilities listed separately (e.g., Arkansas Nuclear 1 listed separate from Arkansas Nuclear 2).

Two Reactors, One Pool - facilities combined (e.g., Braidwood 1 and 2 combined, listed as Braidwood 1).

Two Reactors, Two Pools, With Transfer Canal - facilities combined (e.g., Browns Ferry 1 and 2 combined, but listed separate from Browns Ferry 3).

Included on disk is a spreadsheet (ANN_SHIP_REV.XLS) in zip format (ANN_SHIP_REV.ZIP) that contains the shipment data for the mostly rail and mostly truck scenarios.

Table 2-1. Shipping Container Capacities and Notation

Rail Shipping Containers	Capacity	Comments
B-RAIL-LGSP	61	Large BWR single purpose shipping container
B-RAIL-SMSP	24	Small BWR single purpose shipping container
BP-TRAN-OVLG74	74	Big Rock Point dual purpose shipping container
B-TRAN-OVLG	61	Large BWR dual purpose shipping container
B-TRAN-OVMED	44	Medium BWR dual purpose shipping container
B-TRAN-OVSM	24	Small BWR dual purpose shipping container
B-High Heat Rail	17	BWR high heat shipping container
P-RAIL-LGSP	26	Large PWR single purpose shipping container
P-RAIL-SMSP	12	Small PWR single purpose shipping container
P-RAIL-MOX	9	Mixed oxide SNF shipping container
P-RL-LGSP-ST	12	South Texas single purpose shipping container
P-TRAN-OVLG-YR	36	Yankee Rowe dual purpose shipping container
P-TRAN-OVLG	24	Large PWR dual purpose shipping container
P-TRAN-OVMED	21	Medium PWR dual purpose shipping container
P-TRAN-OVSM	12	Small PWR dual purpose shipping container
P-TRNST-OVLG	12	South Texas dual purpose shipping container
P-High Heat Rail	7	PWR high heat shipping container
B-LWT-GA9I	9	Primary BWR shipping container
B-LWT-GA9II	7	Derated BWR shipping container
B-LWT-GA9III	5	Derated BWR shipping container
B-LWT-GA9IV	4	Derated BWR shipping container
B-LWT-GA9V	2	Derated BWR shipping container
BP-LWT-GA4I	4	Big Rock Point shipping container
B-NLI-1/2	2	Secondary BWR shipping container
P-LWT-GA4I	4	Primary PWR shipping container
P-LWT-GA4II	3	Derated PWR shipping container
P-LWT-GA4III	2	Derated PWR shipping container
P-LWT-GA4I-ST	4	South Texas shipping container
P-LWT-GA4II-ST	3	Derated South Texas shipping container
P-LWT-GA4III-ST	2	Derated South Texas shipping container
P-NLI-1/2	1	Secondary PWR shipping container
P-LWT-MOX	4	Mixed oxide SNF shipping container

3. RADIONUCLIDE INVENTORY

This section describes the radionuclide inventory in commercial pressurized water reactor and boiling water reactor spent nuclear fuel. These inventories were estimated using the Characteristics Data Base, and were based on statistical analysis of age, burnup, and initial enrichments. The primary reference for these inventories is the *Repository Radiation Shielding Design Guide* (CRWMS M&O 1997).

The characteristics of spent nuclear fuel listed in Table 3-1 are expected to bound the majority of spent nuclear fuel received at the repository (CRWMS M&O 1997). For comparison, Table 3-2 lists the average characteristics of spent nuclear fuel expected to be received at the repository (CRWMS M&O 1997).

A small amount of spent nuclear fuel (1,661 metric tons initial heavy metal (MTIHM) from the South Texas Project may contain a combination of initial fuel loading, burnup, and enrichment which may result in radionuclide inventories that exceed those in Table 3-1. These spent nuclear fuel assemblies represent a very minor fraction of the overall spent nuclear fuel expected to be received at the repository. It is also unknown whether these assemblies will be irradiated to their maximum burnup limit. In addition, when the overall age, enrichment, and burnup of all commercial spent nuclear fuel is considered, the radionuclide inventories derived from the characteristics in Table 3-1 will yield a conservative estimate of transportation radiological risks from accidents.

The attached spreadsheet PWR.XLS contains the radionuclide inventory for pressurized water reactor spent nuclear fuel, based on the characteristics listed in Table 3-1, for various shipping container capacities. The attached spreadsheet BWR.XLS contains the radionuclide inventory for boiling water reactor spent nuclear fuel, based on the characteristics listed in Table 3-1, for various shipping container capacities. Included on disk are the two spreadsheets (PWR.XLS and BWR.XLS) in zip format (INV_REV.ZIP).

Table 3-1. Bounding Spent Nuclear Fuel Characteristics

Fuel Type	SNF Population Bounded	Burnup (MWd/MTIHM)	Initial Enrichment (weight %)	Age (years)	Initial Fuel Loading (MTIHM/assembly)
PWR	97.85%	48,086	4.20	10	0.464
BWR	100%	49,000	3.74	10	0.196

Table 3-2. Average Spent Nuclear Fuel Characteristics

Fuel Type	Burnup (MWd/MTIHM)	Initial Enrichment (weight %)	Age (years)	Initial Fuel Loading (MTIHM/assembly)
PWR	39,750	3.72	26.4	0.464
BWR	31,490	3.00	26.5	0.196

4. TRANSPORTATION ROUTING

In order to assess the impacts of radioactive materials transportation, characteristics of the transportation routes used to get from the origin of the shipment to the destination of the shipment must be determined. These route characteristics are quantities such as distance, population density, and weighted population density. Often, population density is binned into three zones: rural, suburban, and urban; where rural is defined as an area with a density of less than 139 people/mi^2, suburban is defined as an area with a density between 139 and 3,326 people/mi^2, and urban is defined as an area with a density greater than 3,326 people/mi^2 Typically, the distance traveled within each population zone is determined, as well as the total distance. In addition, these quantities may be determined on a state-specific level.

In this section, highway and rail routes were analyzed using the routing computer codes HIGHWAY (Johnson et al. 1993a) and INTERLINE (Johnson et al. 1993b). Route characteristics include total shipment distance between each origin and destination, the distances traveled in rural, suburban, and urban population density zones, and the weighted population densities in these population density zones.

The HIGHWAY computer code estimates highway routes for transporting radioactive materials within the United States and Canada. The HIGHWAY database contains over 240,000 miles of interstate highways, U.S. highways, state highways, turnpikes, county roads, and local roads. The database contains more than 20,000 highway segments (known as links) and 13,000 intersections (known as nodes), including nodes for many U.S. Nuclear Regulatory Commission (NRC) and Agreement State-licensed facilities, U.S. Department of Energy (DOE) nuclear facilities, several nuclear facilities in Canada, and airports.

Routes are estimated by minimizing the total impedance of a route, which is a function of distance and driving time between the origin and destination. HIGHWAY also can estimate routes that maximize the use of interstate highways. This feature allows the user to estimate routes for transport of highway route controlled quantity shipments (e.g., spent nuclear fuel and high-level radioactive waste), based on the U.S. Department of Transportation (DOT) regulations contained in 49 CFR 397, Subpart D, *Routing of Class 7 (Radioactive) Materials.* Routes generated using these regulations are sometimes referred to as HM-164 routes, after the DOT docket number that contained the routing regulations (46 FR 5298-5318 1981). These routes follow interstate highways, use interstate bypasses or beltways around cities, and use state-designated preferred routes. The routes estimated in this section conform to applicable guidelines and regulations; therefore, they represent routes that could be used. However, they may not be the actual routes used in the future. HIGHWAY is updated periodically to reflect current road conditions, and it has been validated (Maheras and Pippen 1995) and benchmarked against reported mileage and observations of commercial truck firms.

Highway routes were determined from 81 facilities to the Yucca Mountain repository (see Table 4-1). Ten highway routing cases were analyzed:

1. Highway routes using I-15, the Northern, Western, and Southern beltway around Las Vegas, and U.S. 95 to Yucca Mountain.

Table 4-1. Highway Route Origins

Origin	State	Origin	State
BROWNS FERRY NP	AL	CALLAWAY NP	MO
FARLEY NP	AL	COOPER NP	NE
PALO VERDE NP	AZ	FORT CALHOUN NP	NE
ARKANSAS NP	AR	SEABROOK NP	NH
DIABLO CANYON NP	CA	HOPE CREEK NP	NJ
HUMBOLDT BAY NP	CA	OYSTER CREEK NP	NJ
RANCHO SECO NP	CA	SALEM NP	NJ
SAN ONOFRE NP	CA	FITZPATRICK NP	NY
FT ST VRAIN NP	CO	GINNA NP	NY
CONN YANKEE NP	CT	INDIAN POINT NP	NY
MILLSTONE NP	CT	NINE MILE PNT NP	NY
CRYSTAL RIVER NP	FL	WEST VALLEY RP	NY
ST LUCIE NP	FL	BRUNSWICK NP	NC
TURKEY POINT NP	FL	HARRIS NP	NC
HATCH NP	GA	MCGUIRE NP	NC
VOGTLE NP	GA	DAVIS-BESSE NP	OH
INEEL CHEM PLT	ID	PERRY NP	OH
ARGONNE WEST	ID	TROJAN NP	OR
BRAIDWOOD NP	IL	BEAVER VALLEY NP	PA
BYRON NP	IL	LIMERICK NP	PA
CLINTON NP	IL	PEACH BOTTOM NP	PA
DRESDEN NP	IL	SUSQUEHANNA NP	PA
G E REPRO PLNT	IL	THREE MILE IS NP	PA
LA SALLE NP	IL	CATAWBA NP	SC
QUAD CITIES NP	IL	OCONEE NP	SC
ZION NP	IL	ROBINSON NP	SC
ARNOLD NP	IA	SRS SITE H	SC
WOLF CREEK NP	KS	SUMMER NP	SC
RIVER BEND NP	LA	SEQUOYAH NP	TN
WATERFORD NP	LA	WATTS BAR NP	TN
MAINE YANKEE NP	ME	COMANCHE PEAK NP	TX
CALVERT CLIFFS NP	MD	SOUTH TEXAS NP	TX
PILGRIM NP	MA	VERMONT YANKEE NP	VT
YANKEE-ROWE NP	MA	NORTH ANNA NP	VA
BIG ROCK POINT NP	MI	SURRY NP	VA
COOK NP	MI	Hanford (WYE BARRICADE)	WA
FERMI NP	MI	WNP 1;2;4 NP	WA
PALISADES NP	MI	KEWAUNEE NP	WI
MONTICELLO NP	MN	LA CROSSE BWR NP	WI
PRAIRIE ISLAND NP	MN	POINT BEACH NP	WI
GRAND GULF NP	MS		

Note: *For all origins the destination was* Yucca Mountain, Nevada.

2. Highway routes using I-15 to U.S. 95 in Las Vegas to Yucca Mountain.

3. Highway routes using I-15, the Northern, Western, and Southern beltway around Las Vegas, and U.S. 95 to Yucca Mountain but with I-70 west of Denver blocked.

4. Highway routes using I-15 from Barstow, California to NV 160 at Arden, Nevada to U.S. 95 to Yucca Mountain.

5. Highway routes using I-15 from Barstow, California to CA 127 at Baker, California to NV 373 to U.S. 95 to Yucca Mountain.

6. Highway routes using U.S. 95 from Needles, California to NV 164 at Searchlight, Nevada to I-15 at Nipton, California to CA 127 at Baker, California to NV 373 to U.S. 95 to Yucca Mountain.

7. Highway routes using U.S. 95 from Needles, California to NV 164 at Searchlight, Nevada to I-15 at Nipton, California to NV 160 at Arden, Nevada to U.S. 95 to Yucca Mountain.

8. Highway routes using U.S. 93 alternate from Wendover, Utah to U.S. 93 at Lages, Nevada to U.S. 6 at Ely, Nevada to U.S. 95 at Tonopah, Nevada to Yucca Mountain.

9. Highway routes using U.S. 93 alternate from Wendover, Utah to U.S. 93 at Lages, Nevada to U.S. 6 at Ely, Nevada to NV 318 at Preston, Nevada to U.S. 93 at Hiko, Nevada to I-15 at Garnet, Nevada to the Northern beltway around Las Vegas to U.S. 95 to Yucca Mountain.

10. Highway routes using I-15, the Northern, Western, and Southern Beltway around Las Vegas, and U.S. 95 to Yucca Mountain, but with I-70, I-80, I-90, and I-94 blocked at approximately the 100th meridian, to force shipments to southern routes (e.g., I-40).

Highway routes from various Nevada nodes to Yucca Mountain and Rachel, Nevada were also analyzed and denoted Case 11. Table 4-2 contains a list of link and node deletions for each of these cases.

The INTERLINE computer code is designed to simulate routing of the United States rail system. The INTERLINE database describes the United States railroad system and includes all rail lines except for industrial spurs. Inland and intracoastal waterways and deep water routes are also included in the database. The database contains more than 15,000 rail and barge segments (known as links) and over 13,000 stations, interchange points, ports, and other locations (known as nodes). As with HIGHWAY, INTERLINE includes nodes for many Nuclear Regulatory Commission and Agreement State-licensed facilities, and DOE nuclear facilities.

Currently, there are no specific routing regulations for transporting radioactive material by rail. Therefore, the routes were estimated by minimizing the total impedance, which is a function of distance, mainline classification, and the number of railroads involved in making the shipment, which simulates the process used by railroads to transport commodities. INTERLINE is updated periodically to reflect mergers, abandonment's, and current track conditions; and has been validated (Maheras and Pippen 1995) and benchmarked against reported mileage and observations of commercial rail firms.

Table 4-2. Link and Node Deletions for Highway Routes

Case	Link Deletions	Node Deletions
1	No link deletions required.	No node deletions required.
2	N. Las Vegas NE I15 x215 → Las Vegas NW I215 U95 N. Las Vegas N I15 x48 → Las Vegas NW U95B S573 Las Vegas W U95 U95B → VGT Airport Las Vegas S I15 I 215 → Las Vegas NW I215 U95	No node deletions required.
3	Commerce City S I70 x276 → Denver N I25 I70 Denver N I25 I70 → Arvada S I70 I76 Arvada S I70 I76 → Wheat Ridge NW I70 x266 Wheat Ridge NW I70 x266 → Wheat Ridge NW I70 x265 Wheat Ridge NW I70 x265 → Lakewood W I70 x261 Lakewood W I70 x261 → Pleasant View S I70 x260 Pleasant View S I70 x260 → Empire E I70 x232	No node deletions required.
4	Arden I15 x33 → Las Vegas S I15 I215 Sloan NE I15 x27 → Las Vegas SE I215 S146 Garnet I15 x64 → Nellis AFB NE I15 x58	No node deletions required.
5	Garnet I15 x64 → Nellis AFB NE I15 x58 Baker I15 S127 → Nipton W I15 S164	No node deletions required.
6	Garnet I15 x64 → Nellis AFB NE I15 x58 Baker I15 S127 → Barstow E I15 S58 Nipton W I15 S164 → CANVI15 NIPTSLOA Searchlight U95 S164 → Alunite U93 U95 Kingman NW I40 x48 → Kingman NW U93 S68	No node deletions required.
7	Garnet I15 x64 → Nellis AFB NE I15 x58 Baker I15 S127 → Barstow E I15 S58 Nipton W I15 S164 → Baker I15 S127 Searchlight U95 S164 → Alunite U93 U95 Kingman NW I40 x48 → Kingman NW U93 S68 Arden I15 x33 → Las Vegas S I15 I215 Sloan NE I15 x27 → Las Vegas SE I215 S146	No node deletions required.
8	Fernley NE I80 x48 → Fernley E U50A U95A Lovelock SW I80 x83 → Fallon U50 U95 Battle Mtn NW I80 x229 → Austin Carlin I80 x280 → Eureka NW U50 S278 Wells I80 x352 → Lages U93 U93A Reno → Reno S U395 U395 Reno E I80 x15 → RNO Airport U395 x65	IDNVS51 MTN OWYH IDNVU93 FILEWELL NVORS140 DENILAKE NVORU95 OROVBURN NVUTS233 OASICEDA NVUTS319 PANACEDA NVUTS487 BAKEGARR NVUTU50 BAKEDELT AZNVI15 LITTOVER AZNVS163 DAVILAUG AZNVU93 KINGBOUL CANVI15 NIPTSLOA CANVS127 SHOSAMAR CANVS164 NIPTSEAR CANVS178 SHOSPAHR CANVU395 HALLRENO CANVU395 LEE STEW CANVU50 S LASTEW CANVU6 BISHBASA CANVU95 NEEDLAUG

Table 4-2. Link and Node Deletions for Highway Routes (continued)

Case	Link Deletions	Node Deletions
9	Fernley NE I80 x48 → Fernley E U50A U95A Lovelock SW I80 x83 → Fallon U50 U95 Battle Mtn NW I80 x229 → Austin Carlin I80 x280 → Eureka NW U50 S278 Wells I80 x352 → Lages U93 U93A Reno → Reno S U395 U395 Reno E I80 x15 → RNO Airport U395 x65 Preston NW U6 S318 → Warm Springs Ely SE U50 U6 → Major's Place U50 U93	IDNVS51 MTN OWYH IDNVU93 FILEWELL NVORS140 DENILAKE NVORU95 OROVBURN NVUTS233 OASICEDA· NVUTS319 PANACEDA NVUTS487 BAKEGARR NVUTU50 BAKEDELT AZNVI15 LITTOVER AZNVS163 DAVILAUG AZNVU93 KINGBOUL CANVI15 NIPTSLOA CANVS127 SHOSAMAR CANVS164 NIPTSEAR CANVS178 SHOSPAHR CANVU395 HALLRENO CANVU395 LEE STEW CANVU50 S LASTEW CANVU6 BISHBASA CANVU95 NEEDLAUG
10	Commerce City S I70 x276 → Denver N I25 I70 Denver N I25 I70 → Arvada S I70 I76 Arvada S I70 I76 → Wheat Ridge NW I70 x266 Wheat Ridge NW I70 x266 → Wheat Ridge NW I70 x265 Wheat Ridge NW I70 x265 → Lakewood W I70 x261 Lakewood W I70 x261 → Pleasant View S I70 x260 Pleasant View S I70 x260 → Empire E I70 x232 Omaha SW I680 I80 → Omaha SW I80 x445 Omaha SW I80 x445 → Papillion W I80 x440 Papillion W I80 x440 → Waverly SW I80 x409 Cheyenne SW I25 I80 → Laramie S I80 x313 Kansas City W I435 I70 → Bonner Springs N I70 x224 Bonner Springs N I70 x224 → Lawrence NE I70 x204 Salina NW I135 I170 → Ellsworth NE I70 x225 Fargo SW I29 I94 → West Fargo I94 x344 West Fargo I94 x344 → Casselton I94 x331 Sioux Falls NW I29 → Salem S I90 x363 Salem S I90 x363 → Alexandria I90 x344	No node deletions required.
11	File NVHH-00.PRN: Case 8 link deletions plus Yucca Mountain → Amargosa Valley U95 S373 File NVHH-01.PRN: Case 9 link deletions plus Yucca Mountain → EMAD Hiko S U93 S375 → Garnet I15 x64	File NVHH-00.PRN: Case 8 node deletions. File NVHH-01.PRN: Case 9 node deletions.

Six destinations within the State of Nevada were evaluated in the rail routing analysis:

1) Apex (node 14763)
2) Arden (node 14768)
3) Beowawe (node 14791)
4) Caliente (node 14770)
5) Dike (node 16334)
6) Jean (node 16328)

These destinations correspond to the likely locations of potential intermodal transfer facilities or origins of rail lines that would be built to the Yucca Mountain Repository. Table 4-3 contains the node numbers for the origins. In some cases, a nuclear facility did not have direct rail access. In these cases, a nearby rail node was chosen (see Table 4-3). Table 4-3 also contains the distance from the facility to the nearby rail node. In addition, if more than one railroad served an origin or destination, both options were run, and the minimum impedance run was chosen. The INTERLINE rail network reflects the merger between the Southern Pacific and the Union Pacific. The combined Union Pacific and Southern Pacific network is denoted Union Pacific in the INTERLINE database. The INTERLINE rail network also reflects the granting of trackage rights to the Burlington Northern Santa Fe over Southern Pacific and Union Pacific track in northern Nevada as a part of the merger agreement. As a result of this granting of trackage rights to the Burlington Northern Santa Fe in northern Nevada, Beowawe may be served by either the Union Pacific or the Burlington Northern Santa Fe. Barge routes from 14 sites that have waterway access, do not have direct rail access, and are not forecast to use truck shipping containers were also determined. The barge routing was done in multiple steps, from the origin to a nearby intermediate barge node to the corresponding intermediate rail node to the six Nevada rail destinations (see Table 4-4).

Four rail routing cases were analyzed:

1. Rail routing to the six Nevada nodes [Apex (node 14763), Arden (node 14768), Beowawe (node 14791), Caliente (node 14770), Dike (node 16334), and Jean (node 16328)].
2. Rail routing to the six Nevada nodes with node 14762 (Las Vegas) blocked.
3. Rail routing to the six Nevada nodes with nodes 14762 (Las Vegas) and 14821 (Reno) blocked.
4. Barge and rail routing from 14 sites without direct rail access to the six Nevada nodes.

Table 4-5 contains a summary of the route characteristics for five Nevada heavy haul truck routes and five Nevada rail routes. These routes originate at the rail nodes listed above and terminate at the Yucca Mountain repository.

Included on disk, but not printed in this section due to length, is the detailed HIGHWAY and INTERLINE output. Table 4-6 contains an index of the filenames for the output.

Table 4-3. Direct and Indirect Rail Access Nodes[a]

Direct Rail Access			
Site	**Rail Node**	**Site**	**Rail Node**
FARLEY NP, AL	15449	SEABROOK NP, NH	144
PALO VERDE NP, AZ	12893	FITZPATRICK NP, NY	783
ARKANSAS NP, AR	9428	NINE MILE POINT NP, NY	782
HUMBOLDT BAY NP, CA	14307	WEST VALLEY, NY	851
RANCHO SECO NP, CA	14389	BRUNSWICK NP, NC	15354
SAN ONOFRE NP, CA	14711	HARRIS NP, NC	7425
MILLSTONE NP, CT	557	MCGUIRE NP, NC	15329
CRYSTAL RIVER NP, FL	15426	DAVIS BESSE NP, OH	14982
HATCH NP, GA	15395	PERRY NP, OH	14963
VOGTLE NP, GA	15392	TROJAN NP, OR	16228
INEEL, ID (Scoville)	13336	BEAVER VALLEY NP, PA	2093
BRAIDWOOD NP, IL	4108	LIMERICK NP, PA	1456
BYRON NP, IL	15091	SUSQUEHANNA NP, PA	1656
CLINTON NP, IL	4835	THREE MILE ISLAND NP, PA	1483
DRESDEN NP, IL	16819	CATAWBA NP, SC	15365
MORRIS, IL (GE Repro Plnt)	16818	ROBINSON NP, SC	7655
LA SALLE NP, IL	15098	SRS, SC	15359
QUAD CITIES NP, IL	4276	SUMMER NP, SC	15364
ZION NP, IL	4083	SEQUOYAH NP, TN	15313
ARNOLD NP, IA	15674	WATTS BAR NP, TN	15315
WOLF CREEK NP, KS	15880	COMANCHE PEAK NP, TX	16014
RIVER BEND NP, LA	15514	SOUTH TEXAS NP, TX	15983
WATERFORD NP, LA	9005	VERMONT YANKEE NP, VT	252
MAINE YANKEE NP, ME	2582	NORTH ANNA NP, VA	15260
COOK NP, MI	5180	HANFORD, WA	16212
FERMI NP, MI	15025	WNP 2 NP, WA	16213
MONTICELLO NP, MN	15607	LA CROSSE NP, WI	15238
PRAIRIE ISLAND NP, MN	9802		

Table 4-3. Direct and Indirect Rail Access Nodes[a] (continued)

Indirect Rail Access			
Site	**Rail Access**	**Rail Node**	**Distance From Site to Rail Access (mi)**
BROWNS FERRY NP, AL	DECATUR JCT, AL	8765	34.4
DIABLO CANYON NP, CA	SAN LUIS OBISPO, CA	16313	27.0
FORT ST. VRAIN NP, CO	MILLIKEN, CO	13711	15.1
HADDAM NECK NP, CT	MIDDLETOWN, CT	571	10.3
ST. LUCIE NP, FL	FORT PIERCE, FL	8471	14.5
TURKEY POINT NP, FL	HOMESTEAD, FL	8519	10.8
CALVERT CLIFFS NP, MD	CHALK POINT, MD	2582	26.0
PILGRIM NP, MA	PLYMOUTH, MA	397	5.4
YANKEE-ROWE NP, MA	HOOSAC TUNNEL, MA	439	6.3
BIG ROCK POINT NP, MI	PETOSKEY, MI	5508	12.4
PALISADES NP, MI	HARTFORD, MI	5186	26.0
GRAND GULF NP, MS	VICKSBURG, MS	8908	29.7
CALLAWAY NP, MO	FULTON, MO	10462	11.5
COOPER NP, NE	NEBRASKA CITY, NE	11534	33.4
FORT CALHOUN NP, NE	BLAIR, NE	11341	3.7
HOPE CREEK NP, NJ	BRIDGETON, NJ	1365	31.7
OYSTER CREEK NP, NJ	LAKEHURST, NJ	1306	17.7
SALEM NP, NJ	SALEM, NJ	2452	13.2
GINNA NP, NY	WEBSTER, NY	14894	21.8
INDIAN POINT NP, NY	CROTON-ON-HUDSON, NY	1073	8.8
PEACH BOTTOM NP, PA	YORK, PA	2432	36.6
OCONEE NP, SC	CLEMSON, SC	7759	10.9
SURRY NP, VA	WAKEFIELD, VA	6044	46.7
KEWAUNEE NP, WI	KEWAUNEE, WI	5812	6.0
POINT BEACH NP, WI	MANITOWOC, WI	5809	22.6

a. The destination rail nodes for all sites were Apex (node 14763), Arden (node 14768), Beowawe (node 14791), Caliente (node 14770), Dike (node 16334), and Jean (node 16328).

Table 4-4. Nodes for Barge Routes[a]

Site	Origin Barge Node	Intermediate Barge Node	Intermediate Rail Node[a]
Browns Ferry NP Dock, AL	16812	16587 (Wilson L/D)	8782 (Sheffield)
Diablo Canyon NP Dock, CA	16837	17292 (Port Hueneme)	14701 (Oxnard)
St. Lucie NP Dock, FL	16815	16703 (Port Everglades)	8514 (Fort Lauderdale)
Turkey Point NP Dock, FL	16814	16917 (Port of Miami)	8521 (Miami)
Calvert Cliffs NP Dock, MD	16968	16969 (Port of Baltimore)	2516 (Baltimore)
Palisades NP Dock, MI	17268	17269 (Port of Muskegon)	5463 (Muskegon)
Grand Gulf NP Dock, MS	16816	17081 (Port of Vicksburg)	8908 (Vicksburg)
Cooper NP Dock, NE	17144	17145 (Port of Omaha)	11557 (Omaha)
Hope Creek NP Dock, NJ	16979	16972 (Port of Wilmington)	2456 (Wilmington)
Oyster Creek NP Dock, NJ	16828	16991 (Port of Newark)	1245 (Oak Island)
Salem NP Dock, NJ	16980	16972 (Port of Wilmington)	2456 (Wilmington)
Surry NP Dock, VA	16959	16956 (Port of Norfolk)	6003 (Norfolk)
Kewaunee NP Dock, WI	16820	16732 (Sturgeon Bay Canal) to 17274 (Port of Milwaukee)	5841 (Milwaukee)
Point Beach NP Dock, WI	16821	16732 (Sturgeon Bay Canal) to 17274 (Port of Milwaukee)	5841 (Milwaukee)

[a] The destination rail nodes for all sites were Apex (node 14763), Arden (node 14768), Beowawe (node 14791), Caliente (node 14770), Dike (node 16334), and Jean (node 16328).

Table 4-5. Route Characteristics for Regional Routes

Corridor	Type	Rail Origin	Distance (mi)			
			Rural	Suburban	Urban	Total
Sloan/Jean	heavy haul	Arden	113.6	4.4	0.0	118.0
Apex	heavy haul	Apex	113.2	0.8	0.0	114.0
Caliente	heavy haul	Caliente	331.0	0.0	0.0	331.0
Caliente-Chalk Mountain	heavy haul	Caliente	175.0	0.0	0.0	175.0
Caliente-Las Vegas	heavy haul	Caliente	233.2	0.8	0.0	234.0
Carlin	rail	Beowawe	323.0	0.0	0.0	323.0
Caliente	rail	Caliente	319.0	0.0	0.0	319.0
Valley Modified	rail	Apex	98.0	0.0	0.0	98.0
Jean	rail	Jean	112.0	0.0	0.0	112.0
Caliente-Chalk Mountain	rail	Caliente	214.0	0.0	0.0	214.0

Table 4-6. Filename Index

ZIP File Name	ZIP File Contents File Names	Description
BELTWAY.ZIP	BT_MAP.*	Case 1 ZIP file containing HIGHWAY output
SPAGBOWL.ZIP	ST_MAP.*	Case 2 ZIP file containing HIGHWAY output
DENVER.ZIP	DBT_MAP.*	Case 3 ZIP file containing HIGHWAY output
C1T.ZIP	C1T_MAP.*	Case 4 ZIP file containing HIGHWAY output
C2T.ZIP	C2T_MAP.*	Case 5 ZIP file containing HIGHWAY output
C3T.ZIP	C3T_MAP.*	Case 6 ZIP file containing HIGHWAY output
C4T.ZIP	C4T_MAP.*	Case 7 ZIP file containing HIGHWAY output
C5T.ZIP	C5T_MAP.*	Case 8 ZIP file containing HIGHWAY output
C6T.ZIP	C6T_MAP.*	Case 9 ZIP file containing HIGHWAY output
SOUTH.ZIP	SOUTH.*	Case 10 ZIP file containing HIGHWAY output
NVHH.ZIP	NVHH-00.PRN NVHH-01.PRN	Case 11 ZIP file containing HIGHWAY output

Zip File Contents File Names	Description
*.PRN	HIGHWAY output
*.OUT	Map file output
*.SI	Origin name, origin state, destination name, destination state, the distance traveled in the rural, suburban, and urban population zones (km), and the weighted population densities in the rural, suburban, and urban population zones (people/km^2).
*.US	Origin name, origin state, destination name, destination state, the distance traveled in the rural, suburban, and urban population zones (miles), and the weighted population densities in the rural, suburban, and urban population zones (people/mi^2).
*.DNS	Origin name, origin state, destination name, destination state, the population zone (rural, suburban, urban, or total), and the distance traveled in each state (miles) for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific distance traveled in each population zone (rural, suburban, urban, and total).
*.WDS	Origin name, origin state, destination name, destination state, the population zone (rural, suburban, urban, or total), and the weighted population density (people/mi^2) for travel in each state for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific weighted population density for travel in each population zone (rural, suburban, urban, and total).

Table 4-6. Filename Index (continued)

ZIP File Name	ZIP File Contents File Names	Destination	Description
RR-CLR.ZIP	BE_RAIL.* CA_RAIL.* DI_RAIL.* JE_RAIL.* AP_RAIL.* AR_RAIL.*	Beowawe Caliente Dike Jean Apex Arden	Case 1 ZIP file containing INTERLINE output
RR-BLK.ZIP	BE_LAS.* CA_LAS.* DI_LAS.* JE_LAS.* AP_LAS.* AR_LAS.*	Beowawe Caliente Dike Jean Apex Arden	Case 2 ZIP file containing INTERLINE output
LASRNO.ZIP	BELASRNO.* CALASRNO.* DILASRNO.* JELASRNO.* APLASRNO.* ARLASRNO.*	Beowawe Caliente Dike Jean Apex Arden	Case 3 ZIP file containing INTERLINE output
BARGE.ZIP	BE_BARGE.* CA_BARGE.* DI_BARGE.* JE_BARGE.* AP_BARGE.* AR_BARGE.*	Beowawe Caliente Dike Jean Apex Arden	Case 4 ZIP file containing INTERLINE output

Zip File Contents File Names	Description
*.PRN	INTERLINE output
*.OUT	Map file output
*.SI	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the distance traveled in the rural, suburban, and urban population zones (km), and the weighted population densities in the rural, suburban, and urban population zones (people/km^2).
*.US	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the distance traveled in the rural, suburban, and urban population zones (miles), and the weighted population densities in the rural, suburban, and urban population zones (people/mi^2).
*.DNS	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the population zone (rural, suburban, urban, or total), and the distance traveled in each state (miles) for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific distance traveled in each population zone (rural, suburban, urban, and total).
*.WDS	Origin name (including node and railroad), origin state, destination name (including node and railroad), destination state, the population zone (rural, suburban, urban, or total), and the weighted population density (people/mi^2) for travel in each state for the population zone. Each origin/destination pair contains 4 rows, one for the state-specific weighted population density for travel in each population zone (rural, suburban, urban, and total).

5. POPULATIONS ALONG TRANSPORTATION ROUTES

The purpose of this chapter is to present the exposed populations along truck and rail transport routes based on the routing cases outlined in Chapter 4. These exposed populations were determined out to 800 meters from either side of the routes, using the routes and population densities estimated by the HIGHWAY and INTERLINE routing computer codes. Exposed populations were also calculated based on the generic population densities of 6 people/km^2 for rural areas, 719 people/km^2 for suburban areas, and 3,861 people/km^2 for urban areas. The method used to estimate the exposed populations does not multiple count the exposed population in areas where routes from several sites converge on to a single route.

For truck transportation, the exposed populations were determined for two shipping scenarios, shipments from 81 sites and shipments from nine sites. This included both commercial nuclear facilities and DOE facilities. In addition, the exposed populations for each scenario were determined for the nine highway routing cases outlined in Chapter 4. The 81-site scenario corresponds to the mostly truck transport scenario presented in Chapter 2. The nine-site scenario corresponds to the mostly rail scenario presented in Chapter 2. The nine sites are the sites where a truck spent nuclear fuel shipping container must be used due to facility constraints. The nine truck sites are Crystal River, Ginna, Haddam Neck (Connecticut Yankee), Humboldt Bay, Indian Point, La Crosse, Monticello, Pilgrim, and St. Lucie 1. Under this scenario, the remainder 72 sites would ship by rail or barge. The ten highway routing cases were:

1. Highway routes using I-15, the Northern, Western, and Southern beltway around Las Vegas, and U.S. 95 to Yucca Mountain.
2. Highway routes using I-15 to U.S. 95 in Las Vegas to Yucca Mountain.
3. Highway routes using I-15, the Northern, Western, and Southern beltway around Las Vegas, and U.S. 95 to Yucca Mountain but with I-70 west of Denver blocked.
4. Highway routes using I-15 from Barstow, California to NV 160 at Arden, Nevada to U.S. 95 to Yucca Mountain.
5. Highway routes using I-15 from Barstow, California to CA 127 at Baker, California to NV 373 to U.S. 95 to Yucca Mountain.
6. Highway routes using U.S. 95 from Needles, California to NV 164 at Searchlight, Nevada to I-15 at Nipton, California to CA 127 at Baker, California to NV 373 to U.S. 95 to Yucca Mountain.
7. Highway routes using U.S. 95 from Needles, California to NV 164 at Searchlight, Nevada to I-15 at Nipton, California to NV 160 at Arden, Nevada to U.S. 95 to Yucca Mountain.
8. Highway routes using U.S. 93 alternate from Wendover, Utah to U.S. 93 at Lages, Nevada to U.S. 6 at Ely, Nevada to U.S. 95 at Tonopah, Nevada to Yucca Mountain.

9. Highway routes using U.S. 93 alternate from Wendover, Utah to U.S. 93 at Lages, Nevada to U.S. 6 at Ely, Nevada to NV 318 at Preston, Nevada to U.S. 93 at Hiko, Nevada to I-15 at Garnet, Nevada to the Northern beltway around Las Vegas to U.S. 95 to Yucca Mountain.

10. Highway routes using I-15, the Northern, Western, and Southern Beltway around Las Vegas, and U.S. 95 to Yucca Mountain, but with I-70, I-80, I-90, and I-94 blocked at approximately the 100th meridian, to force shipments to southern routes (e.g., I-40).

Table 5-1 contains the detailed exposed population estimates for the truck transportation scenarios and cases. The estimates are presented for the total population along the routes and for population in the State of Nevada.

For rail transportation, the exposed populations were determined for the mostly rail shipping scenario outlined in Chapter 2. In addition, the exposed populations were determined for the 4 rail routing cases outlined in Chapter 4. The exposed populations were also separately determined for rail shipments of Naval spent nuclear fuel from the Idaho National Environmental Engineering Laboratory to Nevada. As in Chapter 2, six destinations within the State of Nevada were evaluated:

1) Apex (node 14763)
2) Arden (node 14768)
3) Beowawe (node 14791)
4) Caliente (node 14770)
5) Dike (node 16334)
6) Jean (node 16328)

These destinations correspond to the likely locations of potential intermodal transfer facilities or origins of rail lines that would be built to the Yucca Mountain Repository. The four rail routing cases were:

1. Rail routing to the six Nevada nodes [Apex (node 14763), Arden (node 14768), Beowawe (node 14791), Caliente (node 14770), Dike (node 16334), and Jean (node 16328)].

2. Rail routing to the six Nevada nodes with node 14762 (Las Vegas) blocked.

3. Rail routing to the six Nevada nodes with nodes 14762 (Las Vegas) and 14821 (Reno) blocked.

4. Barge and rail routing from 14 sites without direct rail access to the six Nevada nodes.

Table 5-2 contains the detailed exposed population estimates for the rail transportation cases. The estimates are presented for the total population along the routes and for population in the State of Nevada. Table 5-3 contains the exposed population estimates for travel from the Nevada rail nodes to the repository, along both rail corridors and heavy haul truck routes. Included on disk are the detailed population estimates for each state. Table 5-4 contains an index of filenames for truck transport. Table 5-5 contains an index of filenames for rail transport.

Table 5-1. Exposed Populations for Truck Transport

Case	Number of Sites	Total Population		Nevada Population	
		Actual Densities	Generic[a] Densities	Actual Densities	Generic[a] Densities
Case 1 Truck	81	7,154,092	13,628,878	22,031	49,418
Case 1 Truck	9	2,477,140	4,786,128	22,031	49,418
Case 2 Truck	81	7,192,147	13,681,476	60,086	102,016
Case 2 Truck	9	2,515,195	4,838,726	60,086	102,016
Case 3 Truck	81	7,060,329	13,460,710	22,031	49,418
Case 3 Truck	9	2,349,743	4,541,732	22,031	49,418
Case 4 Truck	81	7,783,233	14,894,535	56,206	117,300
Case 4 Truck	9	2,547,273	4,955,567	2,131	10,254
Case 5 Truck	81	7,781,224	14,885,409	54,151	107,540
Case 5 Truck	9	2,545,277	4,946,440	79	494
Case 6 Truck	81	7,557,854	14,511,538	230	1,096
Case 6 Truck	9	2,539,755	4,939,592	230	1,096
Case 7 Truck	81	7,559,661	14,519,460	2,282	10,856
Case 7 Truck	9	2,541,563	4,947,514	2,282	10,856
Case 8 Truck	81	6,860,940	13,109,407	59,615	123,604
Case 8 Truck	9	1,999,844	4,036,419	59,615	123,604
Case 9 Truck	81	6,860,969	13,110,228	59,644	124,425
Case 9 Truck	9	1,999,873	4,037,240	59,644	124,425
Case 10 Truck	81	7,581,516	14,526,554	22,031	49,418
Case 10 Truck	9	2,566,537	4,991,955	21,395	46,642

a. Generic exposed populations are based on densities of 6 people/km^2 for rural areas, 719 people/km^2 for suburban areas, and 3,861 people/km^2 for urban areas.

Table 5-2. Exposed Populations for Rail Transport

Case	Nevada Destination	Number of Sites	Total Population		Nevada Population	
			Actual Densities	Generic[a] Densities	Actual Densities	Generic[a] Densities
INEEL Rail	Beowawe	1	29,300	74,881	3,176	8,219
	Caliente	1	94,947	177,751	198	637
	Dike	1	95,252	179,499	503	2,385
	Jean	1	124,800	225,624	30,051	48,510
	Apex	1	95,238	179,417	489	2,303
	Arden	1	124,748	225,298	29,999	48,184
Case 1 Rail	Beowawe	72	10,574,828	18,686,598	52,155	96,725
	Caliente	72	10,525,724	18,468,462	30,085	48,721
	Dike	72	10,797,439	18,906,313	30,085	48,721
	Jean	72	10,926,250	19,191,410	30,085	48,721
	Apex	72	10,797,439	18,906,313	30,085	48,721
	Arden	72	10,797,439	18,906,313	30,085	48,721
Case 2 Rail	Beowawe	72	10,574,828	18,686,598	52,155	96,725
	Caliente	72	10,487,343	18,578,056	51,090	91,962
	Dike	72	10,487,646	18,579,804	51,393	93,710
	Jean	72	11,262,333	19,921,517	51,042	91,554
	Apex	72	10,487,633	18,579,722	51,380	93,628
	Arden	72	11,262,385	19,921,843	51,094	91,880
Case 3 Rail	Beowawe	72	10,480,232	18,523,892	4,602	14,899
	Caliente	72	10,396,481	18,427,447	4,271	14,237
	Dike	72	10,396,785	18,429,195	4,575	15,985
	Jean	72	11,141,585	19,712,357	4,224	13,829
	Apex	72	10,396,771	18,429,113	4,561	15,903
	Arden	72	11,141,637	19,712,683	4,276	14,155
Case 4 Rail[b]	Beowawe	72	10,394,060	18,258,218	52,155	96,725
	Caliente	72	10,194,217	17,849,122	30,085	48,721
	Dike	72	10,465,933	18,286,974	30,085	48,721
	Jean	72	10,293,507	18,026,413	30,085	48,721
	Apex	72	10,465,933	18,286,974	30,085	48,721
	Arden	72	10,465,933	18,286,974	30,085	48,721

a. Generic exposed populations are based on densities of 6 people/km^2 for rural areas, 719 people/km^2 for suburban areas, and 3,861 people/km^2 for urban areas.

b. 14 sites ship by barge and rail, 58 sites ship by rail.

Table 5-3. Exposed Populations for Rail Corridors and Heavy Haul Routes

Corridor	Type of Route	Rail Origin	Exposed Population[a]
Carlin	rail	Beowawe	4,989
Caliente	rail	Caliente	4,927
Valley Modified	rail	Apex	1,514
Jean	rail	Jean	1,730
Caliente-Chalk Mountain	rail	Caliente	3,306
Apex	heavy haul	Apex	3,229
Sloan/Jean	heavy haul	Arden	9,899
Caliente	heavy haul	Caliente	5,113
Caliente-Chalk Mountain	heavy haul	Caliente	2,703
Caliente-Las Vegas	heavy haul	Caliente	5,083

a. Exposed populations estimated using densities of 6 people/km^2 for rural areas, 719 people/km^2 for suburban areas, and 3,861 people/km^2 for urban areas.

Table 5-4. Filename Index for Truck Transport

Case	Number of Sites	Filename
Case 1 Truck	81	BT_MAP.POP
Case 1 Truck	9	BR_09.POP
Case 2 Truck	81	ST_MAP.POP
Case 2 Truck	9	SR_09.POP
Case 3 Truck	81	DBT_MAP.POP
Case 3 Truck	9	DBR_09.POP
Case 4 Truck	81	C1T_MAP.POP
Case 4 Truck	9	C1R_09.POP
Case 5 Truck	81	C2T_MAP.POP
Case 5 Truck	9	C2R_09.POP
Case 6 Truck	81	C3T_MAP.POP
Case 6 Truck	9	C3R_09.POP
Case 7 Truck	81	C4T_MAP.POP
Case 7 Truck	9	C4R_09.POP
Case 8 Truck	81	C5T_MAP.POP
Case 8 Truck	9	C5R_09.POP
Case 9 Truck	81	C6T_MAP.POP
Case 9 Truck	9	C6R_09.POP
Case 10 Truck	81	SOUTH.POP
Case 10 Truck	9	SOUTH-09.POP

Note: *Files contained in* TRUCKPOP.ZIP

Table 5-5. Filename Index for Rail Transport

Case	Nevada Destination	Number of Sites	Filename
INEEL Rail	Beowawe	1	BE_USN.POP
	Caliente	1	CA_USN.POP
	Dike	1	DI_USN.POP
	Jean	1	JE_USN.POP
	Apex	1	AP_USN.POP
	Arden	1	AR_USN.POP
Case 1 Rail	Beowawe	72	BE_72.POP
	Caliente	72	CA_72.POP
	Dike	72	DI_72.POP
	Jean	72	JE_72.POP
	Apex	72	AP_72.POP
	Arden	72	AR_72.POP
Case 2 Rail	Beowawe	72	BELAS72.POP
	Caliente	72	CALAS72.POP
	Dike	72	DILAS72.POP
	Jean	72	JELAS72.POP
	Apex	72	APLAS72.POP
	Arden	72	ARLAS72.POP
Case 3 Rail	Beowawe	72	BELR72.POP
	Caliente	72	CALR72.POP
	Dike	72	DILR72.POP
	Jean	72	JELR72.POP
	Apex	72	APLR72.POP
	Arden	72	ARLR72.POP
Case 4 Rail	Beowawe	72	BE_BRG72.POP
	Caliente	72	CA_BRG72.POP
	Dike	72	DI_BRG72.POP
	Jean	72	JE_BRG72.POP
	Apex	72	AP_BRG72.POP
	Arden	72	AR_BRG72.POP

Note: Files contained in RAILPOP.ZIP

6. URBANIZED AREA POPULATION DENSITY

The purpose of this section is to present the population density as a function of distance for the 20 largest urbanized areas in the United States. The 20 largest urbanized areas were identified from Table 8 in the U.S. Bureau of the Census (1992). The central coordinates for these urbanized areas were obtained from the U.S. Bureau of the Census, Census Geographic Information Coding Scheme and are listed in Table 6-1. The populations at 0 to 5 miles, 0 to 10 miles, 0 to 15 miles, 0 to 20 miles, 0 to 25 miles, and 0 to 50 miles from these central points were obtained from the U.S. Environmental Protection Agency Geographic Information Query System (see Table 6-2). These populations are based on 1990 census data. Based on these data and areas, population densities were determined for 0 to 5 miles, 5 to 10 miles, 10 to 15 miles, 15 to 20 miles, 20 to 25 miles, and 25 to 50 miles (see Table 6-2).

Included on disk in zip format (POPDENS.ZIP) is the data from the U.S. Environmental Protection Agency Geographic Information Query System and a spreadsheet (POPDENS.XLS) that contains the data in Table 6-2.

Table 6-1. Coordinates of 20 Largest Urbanized Areas in the United States

Urbanized Area	State	Population	North Latitude	West Longitude
New York	NY	16,044,012	40.669800	073.943849
Los Angeles	CA	11,402,946	34.112101	118.411201
Chicago	IL	6,792,087	41.837050	087.684965
Philadelphia	PA	4,222,211	40.006817	075.134678
Detroit	MI	3,697,529	42.383100	083.102198
San Francisco	CA	3,629,516	37.793250	122.554783
Washington	DC	3,363,031	38.905050	077.016167
Dallas	TX	3,198,259	32.794151	096.765249
Houston	TX	2,901,851	29.768700	095.386728
Boston	MA	2,775,370	42.336029	071.017892
San Diego	CA	2,348,417	32.814950	117.135770
Atlanta	GA	2,157,806	33.762900	084.422592
Minneapolis-St. Paul	MN	2,079,676	44.961850	093.266849
Phoenix	AZ	2,006,239	33.542550	112.071399
St. Louis	MO	1,946,526	38.636050	090.244299
Miami	FL	1,914,660	25.775667	080.210845
Baltimore	MD	1,889,873	39.300800	076.610616
Seattle	WA	1,744,086	47.621800	122.350326
Tampa	FL	1,708,710	27.959000	082.482120
Pittsburgh	PA	1,678,745	40.439207	079.976702

Table 6-2. Population Densities for 20 Largest Urbanized Areas in the United States

Urbanized Area	0-5 mi. Population	0-5 mi. Area (mi^2)	0-5 mi. Population Density (people per mi^2)		
New York	2413349	78.54	30727.71		
Los Angeles	489343	78.54	6230.51		
Chicago	945910	78.54	12043.70		
Philadelphia	964127	78.54	12275.65		
Detroit	583922	78.54	7434.73		
San Francisco	118846	78.54	1513.19		
Washington	116709	78.54	1485.99		
Dallas	303019	78.54	3858.16		
Houston	343661	78.54	4375.63		
Boston	510758	78.54	6503.17		
San Diego	310511	78.54	3953.55		
Atlanta	278977	78.54	3552.05		
Minneapolis	437719	78.54	5573.21		
Phoenix	322022	78.54	4100.11		
St. Louis	435843	78.54	5549.33		
Miami	446398	78.54	5683.72		
Baltimore	688643	78.54	8768.07		
Seattle	326563	78.54	4157.93		
Tampa	220695	78.54	2809.98		
Pittsburgh	467205	78.54	5948.64		
Average			**6827.25**		
Median			**5561.27**		

Table 6-2. Population Densities for 20 Largest Urbanized Areas in the United States (Continued)

Urbanized Area	0-10 mi. Population	5-10 mi. Population	0-10 mi. Area (mi^2)	5-10 mi. Area (mi^2)	5-10 mi. Population Density (people per mi^2)
New York	5646585	3233236	314.16	235.62	13722.28
Los Angeles	2438718	1949375	314.16	235.62	8273.40
Chicago	2803737	1857827	314.16	235.62	7884.86
Philadelphia	2256395	1292268	314.16	235.62	5484.56
Detroit	1619046	1035124	314.16	235.62	4393.20
San Francisco	850335	731489	314.16	235.62	3104.54
Washington	1133191	1016482	314.16	235.62	4314.08
Dallas	1052542	749523	314.16	235.62	3181.07
Houston	1205918	862257	314.16	235.62	3659.53
Boston	1487676	976918	314.16	235.62	4146.17
San Diego	1114724	804213	314.16	235.62	3413.19
Atlanta	741704	462727	314.16	235.62	1963.87
Minneapolis	1136850	699131	314.16	235.62	2967.20
Phoenix	1097244	775222	314.16	235.62	3290.14
St. Louis	1006196	570353	314.16	235.62	2420.65
Miami	1132069	685671	314.16	235.62	2910.08
Baltimore	1293196	604553	314.16	235.62	2565.80
Seattle	771272	444709	314.16	235.62	1887.40
Tampa	546328	325633	314.16	235.62	1382.03
Pittsburgh	1027917	560712	314.16	235.62	2379.74
Average					**4167.19**
Median					**3235.61**

Table 6-2. Population Densities for 20 Largest Urbanized Areas in the United States (Continued)

Urbanized Area	**0-15 mi. Population**	**10-15 mi. Population**	**0-15 mi. Area (mi^2)**	**10-15 mi. Area (mi^2)**	**10-15 mi. Population Density (people per mi^2)**
New York	8594031	2947446	706.86	392.70	7505.61
Los Angeles	4343424	1904706	706.86	392.70	4850.29
Chicago	3921401	1117664	706.86	392.70	2846.11
Philadelphia	3205782	949387	706.86	392.70	2417.59
Detroit	2595629	976583	706.86	392.70	2486.85
San Francisco	1171885	321550	706.86	392.70	818.82
Washington	1903552	770361	706.86	392.70	1961.71
Dallas	1756113	703571	706.86	392.70	1791.63
Houston	2033792	827874	706.86	392.70	2108.16
Boston	2140985	653309	706.86	392.70	1663.64
San Diego	1645669	530945	706.86	392.70	1352.04
Atlanta	1388961	647257	706.86	392.70	1648.23
Minneapolis	1766034	629184	706.86	392.70	1602.20
Phoenix	1513072	415828	706.86	392.70	1058.90
St. Louis	1518242	512046	706.86	392.70	1303.91
Miami	1785738	653669	706.86	392.70	1664.55
Baltimore	1695532	402336	706.86	392.70	1024.54
Seattle	1330666	559394	706.86	392.70	1424.49
Tampa	854506	308178	706.86	392.70	784.77
Pittsburgh	1362985	335068	706.86	392.70	853.24
Average					**2058.36**
Median					**1655.93**

Table 6-2. Population Densities for 20 Largest Urbanized Areas in the United States (Continued)

Urbanized Area	0-20 mi. Population	15-20 mi. Population	0-20 mi. Area (mi^2)	15-20 mi. Area (mi^2)	15-20 mi. Population Density (people per mi^2)
New York	10808573	2214542	1256.64	549.78	4028.06
Los Angeles	5834798	1491374	1256.64	549.78	2712.68
Chicago	4910350	988949	1256.64	549.78	1798.81
Philadelphia	3906324	700542	1256.64	549.78	1274.23
Detroit	3283622	687993	1256.64	549.78	1251.40
San Francisco	1895905	724020	1256.64	549.78	1316.93
Washington	2454450	550898	1256.64	549.78	1002.04
Dallas	2257861	501748	1256.64	549.78	912.64
Houston	2632073	598281	1256.64	549.78	1088.22
Boston	2641526	500541	1256.64	549.78	910.44
San Diego	1916763	271094	1256.64	549.78	493.10
Atlanta	1907374	518413	1256.64	549.78	942.95
Minneapolis	2076207	310173	1256.64	549.78	564.18
Phoenix	1882590	369518	1256.64	549.78	672.12
St. Louis	1932323	414081	1256.64	549.78	753.18
Miami	2166594	380856	1256.64	549.78	692.74
Baltimore	1975834	280302	1256.64	549.78	509.85
Seattle	1711790	381124	1256.64	549.78	693.23
Tampa	1469959	615453	1256.64	549.78	1119.46
Pittsburgh	1629497	266512	1256.64	549.78	484.76
Average					**1161.05**
Median					**927.79**

Table 6-2. Population Densities for 20 Largest Urbanized Areas in the United States (Continued)

Urbanized Area	0-25 mi. Population	20-25 mi. Population	0-25 mi. Area (mi^2)	20-25 mi. Area (mi^2)	20-25 mi. Population Density (people per mi^2)
New York	12353546	1544973	1963.50	706.86	2185.69
Los Angeles	7314098	1479300	1963.50	706.86	2092.78
Chicago	5877814	967464	1963.50	706.86	1368.68
Philadelphia	4481402	575078	1963.50	706.86	813.57
Detroit	3656894	373272	1963.50	706.86	528.07
San Francisco	2352947	457042	1963.50	706.86	646.58
Washington	3039866	585416	1963.50	706.86	828.19
Dallas	2674810	416949	1963.50	706.86	589.86
Houston	3004669	372596	1963.50	706.86	527.12
Boston	3058818	417292	1963.50	706.86	590.35
San Diego	2133787	217024	1963.50	706.86	307.03
Atlanta	2285734	378360	1963.50	706.86	535.27
Minneapolis	2202620	126413	1963.50	706.86	178.84
Phoenix	2043024	160434	1963.50	706.86	226.97
St. Louis	2129596	197273	1963.50	706.86	279.08
Miami	2448845	282251	1963.50	706.86	399.30
Baltimore	2302636	326802	1963.50	706.86	462.33
Seattle	2031166	319376	1963.50	706.86	451.82
Tampa	1805423	335464	1963.50	706.86	474.58
Pittsburgh	1909659	280162	1963.50	706.86	396.35
Average					**694.12**
Median					**527.59**

Table 6-2. Population Densities for 20 Largest Urbanized Areas in the United States (Continued)

Urbanized Area	0-50 mi. Population	25-50 mi. Population	0-50 mi. Area (mi^2)	25-50 mi. Area (mi^2)	25-50 mi. Population Density (people per mi^2)
New York	16745143	4391597	7853.98	5890.49	745.54
Los Angeles	11995083	4680985	7853.98	5890.49	794.67
Chicago	7997522	2119708	7853.98	5890.49	359.85
Philadelphia	7417369	2935967	7853.98	5890.49	498.43
Detroit	4645291	988397	7853.98	5890.49	167.80
San Francisco	5343862	2990915	7853.98	5890.49	507.75
Washington	5590633	2550767	7853.98	5890.49	433.03
Dallas	3923686	1248876	7853.98	5890.49	212.02
Houston	3680606	675937	7853.98	5890.49	114.75
Boston	5998075	2939257	7853.98	5890.49	498.98
San Diego	2530629	396842	7853.98	5890.49	67.37
Atlanta	3099872	814138	7853.98	5890.49	138.21
Minneapolis	2648573	445953	7853.98	5890.49	75.71
Phoenix	2184434	141410	7853.98	5890.49	24.01
St. Louis	2566376	436780	7853.98	5890.49	74.15
Miami	3446036	997191	7853.98	5890.49	169.29
Baltimore	5520605	3217969	7853.98	5890.49	546.30
Seattle	2983686	952520	7853.98	5890.49	161.70
Tampa	2792637	987214	7853.98	5890.49	167.59
Pittsburgh	2969521	1059862	7853.98	5890.49	179.93
Average					**296.85**
Median					**174.61**

7. IMPACTS OF HISTORICAL, REASONABLY FORESEEABLE, AND GENERAL TRANSPORTATION

7.1 RADIOLOGICAL IMPACTS

The cumulative impacts of the transportation of radioactive material consist of impacts from:

- historical shipments of radioactive waste and spent nuclear fuel to the Nevada Test Site
- other historical shipments
- reasonably foreseeable actions that include transportation of radioactive material
- general radioactive materials transportation that is not related to a particular action
- the shipments to the repository

The impacts of shipments to the repository will be analyzed in the Repository Environmental Impact Statement, and will not be discussed in this section. The assessment of cumulative transportation impacts concentrates on the cumulative impacts of offsite transportation, because offsite transportation yields potential radiation doses to a greater portion of the general population than does onsite transportation. The collective dose to the general population and workers was the measure used to quantify cumulative transportation impacts. This measure of impact was chosen because it may be directly related to latent cancer fatalities using a cancer risk coefficient and because of the difficulty in identifying a maximally exposed individual for shipments throughout the United States spanning the periods 1943 through 2033 (91 years) or 1943 through 2047 (105 years). The year 1943 corresponds to the start of operations at the Hanford Site and the Oak Ridge Reservation.

Collective doses from historical shipments of spent nuclear fuel to the Nevada Test Site were summarized in DOE (1996a). Data for these shipments were available for 1971 through 1993 and were linearly extrapolated back to 1951, the start of operations at the Nevada Test Site, because data before 1971 were not available. Collective doses from historical shipments of low-level waste, mixed low-level waste, and transuranic waste to the Nevada Test Site were also estimated (DOE 1996a). Over the time period 1974 through 1994, there were about 8,400 of these shipments. The results of these analysis are summarized in Table 7-1. Collective doses from historical shipments of spent nuclear fuel, low-level waste, mixed low-level waste, and transuranic waste to the Nevada Test Site were estimated to result in a collective dose of 83 person-rem for workers and a collective dose for the general population of 100 person-rem.

Collective doses from other historical shipments of radioactive material were evaluated in DOE (1995a). These include historical shipments associated with the Idaho National Engineering Laboratory, the Savannah River Site, the Hanford Site, the Oak Ridge Reservation, and Naval spent nuclear fuel and test specimens. The results of these analyses are summarized in Table 7-1.

Table 7-1. Historical, Reasonably Foreseeable, and General Transportation-related Collective Radiation Doses and Latent Cancer Fatalities

Category	Collective occupational dose (person-rem)	Collective general Population dose (person-rem)
Historical Transportation		
Nevada Test Site (DOE 1996a)	83	100
Other historical shipments (DOE 1995a)	250	130
Total	330	230
Reasonably foreseeable actions		
Nevada Test Site expanded use (DOE 1996a)	--	150[b]
Spent nuclear fuel management (DOE 1995a, 1996b)	360	810
Waste Management PEIS (DOE 1997a)[a]	16,000	20,000
Waste Isolation Pilot Plant (DOE 1997b)	790	5,900
Mo-99 production (DOE 1996c)	240	520
Tritium supply and recycling (DOE 1995b)	--	--
Surplus HEU disposition (DOE 1996d)	400	520
Storage and Disposition of Fissile Materials (DOE 1996e)	--	2,400[b]
Stockpile Stewardship (DOE 1996f)	--	38[b]
Pantex (DOE 1996g)	250[c]	490[c]
West Valley (DOE 1996h)	1,400	12,000
S3G and D1G prototype reactor plant disposal (DOE 1997c)	2.9	2.2
S1C prototype reactor plant disposal (DOE 1996i)	6.7	1.9
Container system for Naval spent nuclear fuel (USN 1996a)	11	15
Cruiser and submarine reactor plant disposal (USN 1996b)	5.8	5.8
Submarine reactor compartment disposal (USN 1984)	--	0.053
Uranium billets (DOE 1992)	0.50	0.014
Nitric acid (DOE 1995c)	0.43	3.1
Total	19,000	43,000
General transportation		
1943 to 1982	220,000	170,000
1983 to 2033	86,000	94,000
1983 to 2047	110,000	120,000
Total 1943 to 2033	310,000	260,000
Total 1943 to 2047	330,000	290,000
Summary		
Total 1943 to 2033	330,000	300,000
Total 1943 to 2047	350,000	330,000
Total Latent Cancer Fatalities		
Total 1943 to 2033	130	150
Total 1943 to 2047	140	170

a. Includes mixed low-level waste and low-level waste; transuranic waste included in DOE (1997b).

b. Includes public and occupational collective doses.

c. *Includes all* highly enriched uranium shipped to Y-12.

There are considerable uncertainties in these historical estimates of collective dose. For example, the population densities and transportation routes used in the dose assessments were based on census data for 1990 and the United States highway and rail system as it existed in the 1990s. Using census data for 1990 overestimates historical collective doses because the United States population has continuously increased over the time covered in these assessments. Basing collective dose estimates on the United States highway and rail system as it existed in the 1990s may slightly underestimate doses for shipments that occurred in the 1940s, 1950s, and 1960s, because a larger portion of the transport routes would have been on non-interstate highways where the population may have been slightly closer to the road. Data were not available that correlated transportation routes and population densities for the 1940s, 1950s, 1960s, and 1970s; therefore, it was necessary to use more recent data to make dose estimates. By the 1970s, the structure of the interstate highway system was largely fixed and most shipments would have been made on interstates.

Shipment data were linearly extrapolated for years when data were unavailable, which also results in uncertainty. However, this technique was validated by linearly extrapolating the data in Science Applications International Corporation (1991) for 1973 through 1989 to estimate the number of shipments that took place during the time period 1964 through 1972 (also contained in Science Applications International Corporation 1991). The data in Science Applications International Corporation (1991) could not be used directly because only shipment counts are presented for 1964 through 1982 and no origins or destinations were listed for years before 1983. Based on the data in Science Applications International Corporation (1991), linearly extrapolating the data for 1973 through 1989 overestimates the shipments for 1964 through 1972 by 20 percent when compared to the actual shipment counts for 1964 through 1972.

Transportation impacts may also result from reasonably foreseeable projects, such as the transportation impacts contained in other DOE National Environmental Policy Act analyses. The results of these analyses are summarized in Table 7-1. For some of these analyses, a preferred alternative was not identified or a record of decision has not been issued. In those cases, the alternative that was estimated to result in the largest transportation impact was included in Table 7-1.

There are also reasonably foreseeable projects that involve limited transportation of radioactive material:

- shipment of submarine reactor compartments from the Puget Sound Naval Shipyard to the Hanford Site for burial
- shipment of uranium billets from the Hanford Site to the United Kingdom
- shipment of low specific activity nitric acid from the Hanford Site to the United Kingdom

The results of these analyses are summarized in Table 7-1. While this is not an exhaustive list of projects that may involve limited transportation of radioactive material, it does illustrate that the transportation impacts associated with these types of projects are extremely low when compared to major projects or general transportation.

There are also general transportation activities that take place that are unrelated to the alternatives evaluated in this Environmental Impact Statement or to reasonably foreseeable actions. Examples of these activities are shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of commercial low-level radioactive waste to commercial disposal facilities. The Nuclear Regulatory Commission (NRC) evaluated these types of shipments based on a survey of radioactive materials transportation published in 1975 (NRC 1977a). Categories of radioactive material evaluated in NRC (1977a) included: limited quantity shipments, medical, industrial, fuel cycle, and waste.

The NRC estimated that the annual collective worker dose for these shipments was 5,600 person-rem. The annual collective general population dose for these shipments was estimated to be 4,200 person-rem. Because comprehensive transportation doses were not available, these collective dose estimates were used to estimate transportation collective doses for 1943 through 1982 (40 years). These dose estimates included spent nuclear fuel and radioactive waste shipments made by truck and rail.

Based on the transportation dose assessments in NRC (1977a), the cumulative transportation collective doses for 1943 through 1982 were estimated to be 220,000 person-rem for workers and 170,000 person-rem for the general population.

In 1983, another survey of radioactive materials transportation in the United States was conducted (Javitz et al. 1985). This survey included NRC and Agreement State licensees. Both spent nuclear fuel and radioactive waste shipments were included in the survey. Weiner et al. (1991a and 1991b) used the survey by Javitz et al. (1985) to estimate collective doses from general transportation. The transportation dose assessments in Weiner et al. (1991a and 1991b) were used to estimate transportation doses for 1983 through 2033 (51 years) and 1983 through 2047 (65 years). The intervals 2010 through 2033 and 2010 through 2047 correspond to the intervals of time associated with the shipments to the repository.

Weiner et al. (1991a) evaluated eight categories of radioactive material shipments by truck: industrial, radiography, medical, fuel cycle, research and development, unknown, waste, and other. Based on a median external exposure rate, an annual collective worker dose of 1,400 person-rem and an annual collective general population dose of 1,400 person-rem were estimated. Over the 51 year time period from 1983 through 2033, both the collective worker and general population doses were estimated to be 71,000 person-rem. Over the 65 year time period from 1983 through 2047, both the collective worker and general population doses were estimated to be 91,000 person-rem.

Weiner et al. (1991b) also evaluated six categories of radioactive material shipments by plane: industrial, radiography, medical, research and development, unknown, and waste. Based on a median external exposure rate, an annual collective worker dose of 290 person-rem and an annual collective general population dose of 450 person-rem were estimated. Over the 51 year time period from 1983 through 2033, the collective worker dose was estimated to be 15,000 person-rem and the general population collective dose was estimated to be 23,000 person-rem. Over the 65 year time period from 1983 through 2047, the collective worker dose was estimated to be 19,000 person-rem and the general population collective dose was estimated to be 29,000 person-rem.

Like the historical transportation dose assessments, the estimates of collective doses because of general transportation also exhibit considerable uncertainty. For example, data for 1975 were applied to general transportation activities from 1943 through 1982. This approach probably overestimates doses because the amount of radioactive material that was transported in the 1950s and 1960s was less than the amount shipped in the 1970s. For example, in 1968, the shipping rate for radioactive material packages was estimated to be 300,000 packages per year (Patterson 1968); in 1975 this rate was estimated to be 2,000,000 packages per year (NRC 1977a). However, because comprehensive data that would enable a more realistic transportation dose assessment are not available, the dose estimates developed by the NRC were used.

The total worker and general population collective doses are summarized in Table 7-1. Total collective worker doses from all types of shipments (historical, reasonably foreseeable actions, and general transportation) were estimated to be 330,000 person-rem (130 latent cancer fatalities), for the period of time 1943 through 2033 (91 years). The total collective worker doses were estimated to be 350,000 person-rem (140 latent cancer fatalities), for the period of time 1943 through 2047 (105 years). Total general population collective doses were estimated to be 300,000 person-rem (150 latent cancer fatalities), over the period of time 1943 through 2033. Total general population collective doses were estimated to be 330,000 person-rem (170 latent cancer fatalities), over the period of time 1943 through 2047. The majority of the collective dose for workers and the general population was because of general transportation of radioactive material.

The total number of latent cancer fatalities over the time period 1943 through 2033 was estimated to be 280. Over this same period of time (91 years), approximately 46,000,000 people would die from cancer, based on 510,000 latent cancer fatalities per year (U.S. Bureau of the Census 1993). For the time period 1943 through 2047, the total number of latent cancer fatalities was estimated to be 310. Over this same period of time (105 years), approximately 54,000,000 people would die from cancer. It should be noted that the estimated number of transportation-related latent cancer fatalities would be indistinguishable from other latent cancer fatalities, and the transportation-related latent cancer fatalities would be 0.0006% of the total number of latent cancer fatalities.

7.2 ACCIDENT IMPACTS

For transportation accidents involving radioactive material, the dominant risk is from traffic or vehicular accidents that are unrelated to the radioactive cargo. Typically, the radiological accident risk from transportation accidents is less than 1 percent of the vehicular accident risk. For example, in DOE (1997a), the radiological accident risk over all shipment types was estimated to be 0.37 and the number of vehicular accident fatalities was estimated to be 41; the radiological risk was estimated to be less than 0.9 percent of the total risk from transportation accidents. Therefore, the number of vehicular accident fatalities was used to quantify the cumulative impacts of transportation accidents.

From 1943 through 1997, there have been approximately 2,400,000 people killed in motor vehicle accidents in the United States (NSC 1998). These fatalities include people killed in motor vehicle accidents that happened to involve radioactive material. Based on data from Radioactive Material Incident Report data base, the number of these fatalities is extremely low and no acute radiological fatalities because of a motor vehicle transportation accident have ever occurred in the United States.

For the period 1943 through 2033, it is estimated that about 4,000,000 people would be killed in motor vehicle accidents. For the period 1943 through 2047, it is estimated that about 4,600,000 people would be killed in motor vehicle accidents. The reasonably foreseeable actions listed in Table 7-1 would contribute less than 100 fatalities to this total.

From 1943 through 1997, there have been approximately 140,000 people killed in railroad accidents in the United States (DOT 1993, NSC 1998). These fatalities include people killed in railroad accidents that happened to involve radioactive material. Based on data from Radioactive Material Incident Report data base, the number of these fatalities is extremely low and no acute radiological fatalities because of a rail transportation accident have ever occurred in the United States.

For the period 1943 through 2033, it is estimated that about 180,000 people would be killed in railroad accidents. For the period 1943 through 2047, it is estimated that about 200,000 people would be killed in railroad accidents. The reasonably foreseeable actions listed in Table 7-1 would contribute less than 100 fatalities to this total.

8. STATE-SPECIFIC FOOD TRANSFER FACTORS

In the RADTRAN 4 computer code, population doses via long-term exposure through ingestion are evaluated on the basis of societal dose, where the amount of residual radioactivity contained in agricultural food stuffs is used to estimate the population doses through the ingestion pathway. The transfer of radioactivity deposited on soil to radioactivity in food stuffs is modeled in RADTRAN 4 using food transfer factors. These food transfer factors are radionuclide-specific and have units of curie ingested in food per curie deposited on the ground. In addition, these food transfer factors are dependent on agricultural land use and yield data, which are available at the state level. These state-specific food transfer factors were used to estimate the ingestion doses from transportation accidents in the *Programmatic Spent Nuclear Fuel Management Environmental Impact Statement* (DOE 1995a).

The methods and data used to calculate the food transfer factors are similar to those used in the Nuclear Regulatory Guide 1.109 (NRC 1977b) and the National Council on Radiation Protection and Measurements Commentary No. 3 (NCRP 1989). Three pathways were considered: crops, meat, and milk. For vegetation, three contamination mechanisms were considered: direct deposition, resuspension, and root uptake. The state-specific food transfer factors were based on state-specific crop yields and land use. For meat and milk, the food transfer factors were based on beef cattle and milk cows eating contaminated pasture and stored feed; and (as with crops) the state-specific food transfer factors were based on state-specific crop yields and land use. No credit for interdiction of food stuffs or reduction by activities such as washing was assumed for crops, meat, or milk.

B.M. Biwer has indicated that the state-specific food transfer factors for 184 radionuclides (letter from B.M. Biwer, Argonne National Laboratory, to S.J. Maheras, TRW Environmental Safety Systems, August 19, 1997) are included on disk as a spreadsheet (FOODREV.XLS) in zip format (FOODREV.ZIP).

9. DOSE CONVERSION FACTORS

The RADTRAN 4 (Neuhauser and Kanipe 1994) and RISKIND (Yuan et al. 1995) computer codes require as input dose conversion factors (or dose coefficients) in order to estimate doses through the inhalation, ingestion, immersion, and ground surface pathways. In order to provide consistent dosimetric data bases for RADTRAN 4 and RISKIND, this section contains dose conversion factors from Federal Guidance Report No. 11; *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* (Eckerman et al. 1988), and Federal Guidance Report No. 12; *External Exposure to Radionuclides in Air, Water, and Soil* (Eckerman and Ryman 1993). In order to simplify the construction of RADTRAN 4 and RISKIND input files, the dose conversion factors are provided with the same units as required by the computer codes. The ingestion and inhalation dose conversion factors have units of rem/Ci or Sv/Bq, the immersion dose conversion factors have units of rem-m^3/Ci-s or Sv-m^3/Bq-s, and the ground exposure dose conversion factors have units of MeV or Sv-m^2/Bq-s. The ingestion and inhalation dose conversion factors are based on a 50-year dose commitment period and represent committed effective dose equivalent per unit intake. The immersion and ground surface exposure dose conversion factors represent the effective dose equivalent rate per unit concentration in environmental media (activity per unit area or activity per unit volume). The conversion of the units from Federal Guidance Reports No. 11 and 12 to the units used by RADTRAN 4 is a simple unit conversion for the ingestion, inhalation, and immersion dose conversion factors (e.g., Sv/Bq to rem/Ci). However, it should be noted that MeV is not the traditional unit for ground surface dose conversion factors (units of rem-m^2/Ci-s would be more traditional). These units are necessary because RADTRAN 4 uses the following expression to estimate the dose rate from groundshine:

$$\text{Dose Rate (rem/day)} = \text{Contamination Level } (\mu\text{Ci/m}^2) \times \text{Photon Energy (MeV)} \times$$

$$3.04\text{E}-4\ \frac{\text{rem - m}^2}{\text{day} - \mu\text{Ci} - \text{MeV}}$$

The constant 3.04E-4 relates dose rate to deposited activity, based on dry air, an average photon energy of 0.33 MeV, and a 1 meter exposure distance above the ground (see equation 89 in Neuhauser and Kanipe 1994). The value for MeV for each radionuclide was calculated from the Federal Guidance Report No. 12 ground surface dose conversion factors, converted from units of Sv-m^2/Bq-s to units of rem-m^2/μCi-day, as follows:

$$\text{Dose Conversion Factor } \frac{\text{rem - m}^2}{\mu\text{Ci} - \text{day}} = 3.04\text{E}-4\ \frac{\text{rem - m}^2}{\mu\text{Ci} - \text{day} - \text{MeV}} \times \text{Photon Energy (MeV)}$$

$$\text{Photon Energy (MeV)} = \text{Dose Conversion Factor } \frac{\text{rem - m}^2}{\mu\text{Ci} - \text{day}} \div 3.04\text{E}-4\ \frac{\text{rem - m}^2}{\mu\text{Ci} - \text{day} - \text{MeV}}$$

Included on a disk is a spreadsheet (DCF_REV.XLS) in zip format (DCF_REV.ZIP) that contains the dose conversion factors. Table 9-1 contains lung clearance class [D (days), W (weeks), or Y (years)] and fractional uptake from the small intestine (f_1) assignments for radionuclides commonly analyzed in transportation accidents.

Table 9-1. Radionuclide Clearance Class and Fractional Uptake Assignments

Radionuclide	Lung Clearance Class	Fractional Uptake (f_1)	Comments
H-3	V	1.0	tritiated water vapor
Be-10	Y	0.005	oxide
C-14	-	1.0	CO_2
Cl-36	W	1.0	
Co-60	Y	0.05	oxide
Ni-59	W	0.05	oxide
Ni-63	W	0.05	oxide
Se-79	W	0.8	oxide
Sr-90	D	0.3	soluble salt, not $SrTiO_3$
Y-90	Y	0.0001	oxide
Zr-93	W	0.002	oxide
Nb-93m	Y	0.01	oxide
Nb-94	Y	0.01	oxide
Tc-99	W	0.8	oxide
Ru-106	Y	0.05	oxide
Rh-102	Y	0.05	oxide
Pd-107	Y	0.005	oxide
Cd-113m	Y	0.05	oxide
Sn-126	W	0.02	oxide
Sb-126m	D	0.1	oxide
Sb-126	D	0.1	oxide
Sb-125	D	0.1	oxide
Te-125m	W	0.2	oxide
Te-129m	W	0.2	oxide
Te-129	W	0.2	oxide
I-129	D	1.0	all forms
Cs-134	D	1.0	all forms
Cs-135	D	1.0	all forms
Cs-137	D	1.0	all forms
Ce-144	Y	0.0003	oxide
Pr-144	Y	0.0003	oxide
Pm-147	Y	0.0003	oxide
Sm-151	W	0.0003	all forms
Eu-154	W	0.001	all forms
Eu-155	W	0.001	all forms
Pb-210	D	0.2	all forms
Ra-223	W	0.2	all forms

Table 9-1. Radionuclide Clearance Class and Fractional Uptake Assignments (Continued)

Radionuclide	Lung Clearance Class	Fractional Uptake (f_1)	Comments
Ra-224	W	0.2	all forms
Ra-225	W	0.2	all forms
Ra-226	W	0.2	all forms
Ra-228	W	0.2	all forms
Ac-225	Y	0.001	oxide
Ac-227	Y	0.001	oxide
Ac-228	Y	0.001	oxide
Th-227	Y	0.0002	oxide
Th-228	Y	0.0002	oxide
Th-229	Y	0.0002	oxide
Th-230	Y	0.0002	oxide
Th-231	Y	0.0002	oxide
Th-232	Y	0.0002	oxide
Th-234	Y	0.0002	oxide
Pa-231	Y	0.001	oxide
Pa-233	Y	0.001	oxide
U-232	Y	0.002	insoluble forms, UO_2, U_3O_8
U-233	Y	0.002	insoluble forms, UO_2, U_3O_8
U-234	Y	0.002	insoluble forms, UO_2, U_3O_8
U-235	Y	0.002	insoluble forms, UO_2, U_3O_8
U-236	Y	0.002	insoluble forms, UO_2, U_3O_8
U-238	Y	0.002	insoluble forms, UO_2, U_3O_8
Np-237	W	0.001	all forms
Pu-236	Y	0.00001	oxide
Pu-238	Y	0.00001	oxide
Pu-239	Y	0.00001	oxide
Pu-240	Y	0.00001	oxide
Pu-241	Y	0.00001	oxide
Pu-242	Y	0.00001	oxide
Pu-244	Y	0.00001	oxide
Am-241	W	0.001	all forms
Am-242	W	0.001	all forms
Am-242m	W	0.001	all forms
Am-243	W	0.001	all forms
Cm-242	W	0.001	all forms
Cm-243	W	0.001	all forms
Cm-244	W	0.001	all forms

Table 9-1. Radionuclide Clearance Class and Fractional Uptake Assignments (Continued)

Radionuclide	Lung Clearance Class	Fractional Uptake (f_1)	Comments
Cm-245	W	0.001	all forms
Cm-246	W	0.001	all forms
Cm-247	W	0.001	all forms
Cm-248	W	0.001	all forms
Cf-252	Y	0.001	oxide

10. NATIONAL AVERAGE ATMOSPHERIC CONDITIONS

Joint frequency atmospheric dispersion data consists of a 3-dimensional matrix of windspeed class, stability class, and wind direction. In order to estimate national average atmospheric conditions for use in the RISKIND computer code (Yuan et al. 1995), joint frequency data from 177 sites was averaged and normalized. In performing this averaging and normalization, the directional component of the joint frequency data was condensed to yield a 2-dimensional matrix of stability class and windspeed class, which is the format used by RISKIND. The resulting matrix is contained in Table 10-1.

The joint frequency data was obtained from Yuan et al. (1995). In order to provide a consistent format for RISKIND, only data sets with stability classes A through F or A through G were used. In those cases where a data set contained both stability class F and G, these data were consolidated, again to provide data in a consistent format for RISKIND.

Included on disk is file in zip format (MET.ZIP) that includes a spreadsheet (MET.XLS) that contains the data used to derive Table 10-1. Also included in MET.ZIP are the 177 joint frequency data sets.

Table 10-1. National Average Joint Frequency Distribution

	Windspeed Class						
Stability Class	**Class 1 (0.89 m/s)**	**Class 2 (2.46 m/s)**	**Class 3 (4.47 m/s)**	**Class 4 (6.93 m/s)**	**Class 5 (9.61 m/s)**	**Class 6 (12.52 m/s)**	**Total**
A	0.00667	0.00444	0.00000	0.00000	0.00000	0.00000	0.01111
B	0.02655	0.02550	0.01559	0.00000	0.00000	0.00000	0.06764
C	0.01400	0.02931	0.05724	0.01146	0.00122	0.00028	0.11351
D	0.03329	0.07231	0.15108	0.16790	0.03686	0.01086	0.47230
E	0.00040	0.04989	0.06899	0.00146	0.00016	0.00003	0.12093
F+G	0.12485	0.08856	0.00110	0.00000	0.00000	0.00000	0.21451
Total	0.20576	0.27000	0.29401	0.18082	0.03825	0.01117	1.00000

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APPENDIX A

DATA TRACKING DOCUMENTATION

APPENDIX A

DATA TRACKING DOCUMENTATION

Data Tracking Numbers associated with the developed meteorological and air quality data presented in the figures and tables are shown in this table.

DATA	DTN
From Section 2, spreadsheet on disk ANN_SHIP_REV.XLS containing shipment data for the mostly rail and mostly truck scenarios	MO9902EISEBF22.000 MO9902EISEBF23.000
Table 2-1, Shipping Container Capacities and Notation	MO9902EISEBF21.000
Table 3-1, Bounding Spent Nuclear Fuel Characteristics	MO9902EISEBF31.000
Table 3-2, Average Spent Nuclear Fuel Characteristics	MO9902EISEBF32.000
From Section 3, spreadsheet on disk PWR.XLS containing radionuclide inventory for pressurized water reactor spent nuclear fuel based on bounding and average spent nuclear fuel characteristics	MO9902EISEBF33.000
From Section 3, spreadsheet on disk BWR.XLS containing radionuclide inventory for boiling water reactor spent nuclear fuel based on bounding and average spent nuclear fuel characteristics	MO9902EISEBF34.000
Tables in Section 4 on analysis used for determination of transportation routing	MO9902EISEBF4A.000
Tables in Section 5 on analysis of populations along transportation routes	MO9902EISEBF5A.000
Table 6-1, Coordinates of 20 Largest Urbanized Population and Location of Areas in the United States	MO9902EISEBF61.000
Table 6-2, Population Densities for 20 Largest Urbanized Areas in the United States	MO9902EISEBF62.000
Table 7-1, Historical, Reasonably Foreseeable, and General Transportation-related Collective Radiation Doses and Latent Cancer Fatalities	MO9902EISEBF71.000
From Section 8, spreadsheet on disk FOODREV.XLS containing state-specific food transfer factors for 184 radionuclides	MO9902EISEBF8A.000
Table 9-1, Radionuclide Clearance Class and Fractional Update Assignments	MO9903EISEBF91.000
Table 10-1, National Average Joint Frequency Distribution	MO9903EISEB101.000