E.3.3.5 Ceramic Immobilization Alternative

The ceramic immobilization facility with radionuclides includes a scrap treatment cell to allow treatment of off-specification process materials, contaminated equipment, and components to recover Pu and recycle it back into the process. The cell would be equipped with equipment suitable for size reduction and process feed makeup of off-specification ceramic material from the hot-pressing operations. Decontamination and leaching equipment also would be provided to allow recovery of Pu from process equipment and to return the solutions to the calciner feed makeup process. Other off-specification materials from the process upstream of the hot presses would be recycled to the appropriate equipment in the Pu process. The ceramic immobilization operations would be configured with a minimization of waste products given high priority.

Table E.3.3.5–1 presents the estimated annual waste volumes during construction and operation of the ceramic immobilization facility. As illustrated in Figure E.3.3.5–1, waste management facilities would be provided to monitor, treat, and handle radioactive wastes, including low-level, TRU, and mixed waste. These management facilities would be located in the Radwaste Management Building immediately adjacent to the Plutonium Processing Building. The waste treatment processes include assay examination, sorting, separation, concentration, size reduction, organic destruction, and thermal treatment.

Process liquid waste treatment facilities include the nitric acid recovery system and the LLW/TRU radwaste solidification systems. Since these systems would handle relatively low-activity waste streams, they generally would be located in processing areas outside the main processing canyons. Low-level liquid radwaste treatment systems generally would be located in nonshielded processing rooms equipped with room ventilation confinement zoning appropriate to the expected levels of contamination within the room. Mixed waste would be segregated from other waste forms, and stored for offsite or onsite treatment in accordance with the site treatment plan.

Process solid radioactive waste treatment would also be performed in the Radwaste Management Building. Solid waste generated from glovebox operations for the Pu processing head end (upstream of the addition of cesium) would generally be handled and processed in glovebox enclosures. Where fume or dust generation is anticipated, equipment would be installed in glovebox enclosures supplied with local filters, mist eliminators, condensers, and so forth, as required to minimize the spread of contamination to the glove box ventilation system. Solid waste generated within the process cells would be segregated remotely into low-level contact-handled, low-level remote-handled, TRU, and mixed waste. Solid waste assay, segregation, decontamination, and volume-reduction facilities would be used to minimize the volume of waste shipped from the facility. Waste packaging and shipping facilities for both LLW and TRU waste would be provided.

Gaseous waste would be filtered, condensed, scrubbed, absorbed, and so forth, as required to meet DOE and other applicable regulatory requirements. Local condensers, mist eliminators, and sintered-metal filters with blowback to the process are intended for Pu oxidation, calcination, hot pressing, and other operations where particulate generation would be expected. HEPA filters would be provided at both inlets and outlets of glovebox enclosures handling Pu.

All fire sprinkler water discharged in process areas during and after a fire would be contained, monitored, sampled, and if required, retained until disposal. Utility wastewater discharges (including cooling system and boiler blowdown, cold chemical area liquid effluents, and nonradioactive liquid ceramic additive liquid wastes) would be treated in an industrial wastewater treatment plant prior to discharge in accordance with applicable environmental standards. The facility design includes a sanitary treatment plant to treat liquid sanitary wastes.

High-Level Waste. The ceramic immobilization facility would not generate a HLW stream from processing Pu. However, the facility would produce an immobilized ceramic product spiked with cesium radionuclides. The Pu disposition mission would produce 64 canisters annually (LLNL 1996d:9-2). This immobilized product would require interim storage until a final disposition option becomes available.

Transuranic Waste. TRU wastes would be generated from process and facility operations, equipment decontamination, failed equipment, and used tools. The bellows filling and closure function, as the ceramic calciner powder is assembled and prepared for compression, would generate both liquid and solid TRU waste. The contaminated water from the bellows decontamination would be collected and treated as TRU waste.

Numerous other processes, including those directly supporting the radioactive ceramic production and those managing the various waste streams, would produce used ventilation air filters, as well as contaminated operator clothing, gloves, wipes, shoe covers, and other process equipment. Following characterization, these wastes would be handled, treated, and disposed of according to their level of contamination. If characterized as TRU waste, they would be appropriately treated and stored until final disposal.

Transuranic wastes would be treated in a waste handling facility to form grout or compact solid waste. Any liquid TRU waste would be treated with the remaining TRU sludge being solidified. Treated TRU waste products would be packaged, assayed, and certified to meet the waste acceptance criteria of the WIPP or alternative treatment level. Assuming WIPP is determined to be a suitable repository for these wastes and depending on decisions made in the ROD associated with the supplemental EIS being prepared for the proposed continued phased development of WIPP for disposal of TRU waste, pursuant to the requirements of 40 CFR 191 and 40 CFR 268, these wastes would be transported to WIPP for disposal.

Mixed Transuranic Waste. A very small quantity of solid mixed TRU waste, mainly rubber gloves and leaded glovebox gloves from the waste handling facility, would be generated annually during operations. Mixed TRU would be packaged and shipped to another DOE waste management facility for temporary storage, pending final treatment and disposal in accordance with the site-specific treatment plan that was developed to comply with the *Federal Facility Compliance Act*. This mixed TRU waste would need eventual treatment to meet the WIPP waste acceptance criteria or alternative treatment level.

| **Low-Level Waste.** [Text deleted.] Cesium capsule processing would produce both liquid and solid LLW. Conducted in a shielded cell with manipulators, the cesium processing involves one capsule at a time. The outer capsule is cut open, decontaminated, and discarded as solid LLW. The inner capsule is sheared to expose the cesium and barium chloride solids. The sheared pieces would be leached in hot water and agitated to dissolve the solid salts. The solution would then be transferred to the ion exchange feed tank, and the capsule hull would be decontaminated and disposed of as LLW. The chloride solution would then be processed using a cation exchange column to isolate the radioactive cesium. The effluent from the exchange column would be recycled to the column as necessary to remove residual cesium. The effluent would then be neutralized and sent to waste treatment for solidification as LLW.

Numerous processes, including those directly supporting the radioactive ceramic production and those managing the various waste streams, would produce contaminated operator clothing, gloves, wipes, shoe covers, and process equipment. Following characterization, these wastes would be handled, treated, and disposed of according to their level of contamination. If characterized as LLW, they would be treated by sorting, separation, concentration, and size-reduction processes. Any liquid LLW would be treated with the remaining LLW sludge being solidified.

Mixed Low-Level Waste. A very small quantity of solid mixed LLW, mainly rubber gloves and leaded glovebox gloves from the waste handling facility, would be generated annually during operations. Any mixed LLW would be stored onsite on an interim basis until treatment, disposal, or offsite shipment in accordance with the site-specific treatment plan that was developed to comply with the *Federal Facility Compliance Act*.

Hazardous Waste. Many of the ceramic immobilization facility processes would generate hazardous waste. This waste would include chemical makeup and reagents for support activities and lubricants and oils for process and support equipment. The liquid and solid hazardous waste would be collected at the facility and

stored on an interim basis. The hazardous wastes would be recycled or stored and packaged for offsite treatment or disposal at commercial RCRA-permitted facilities.

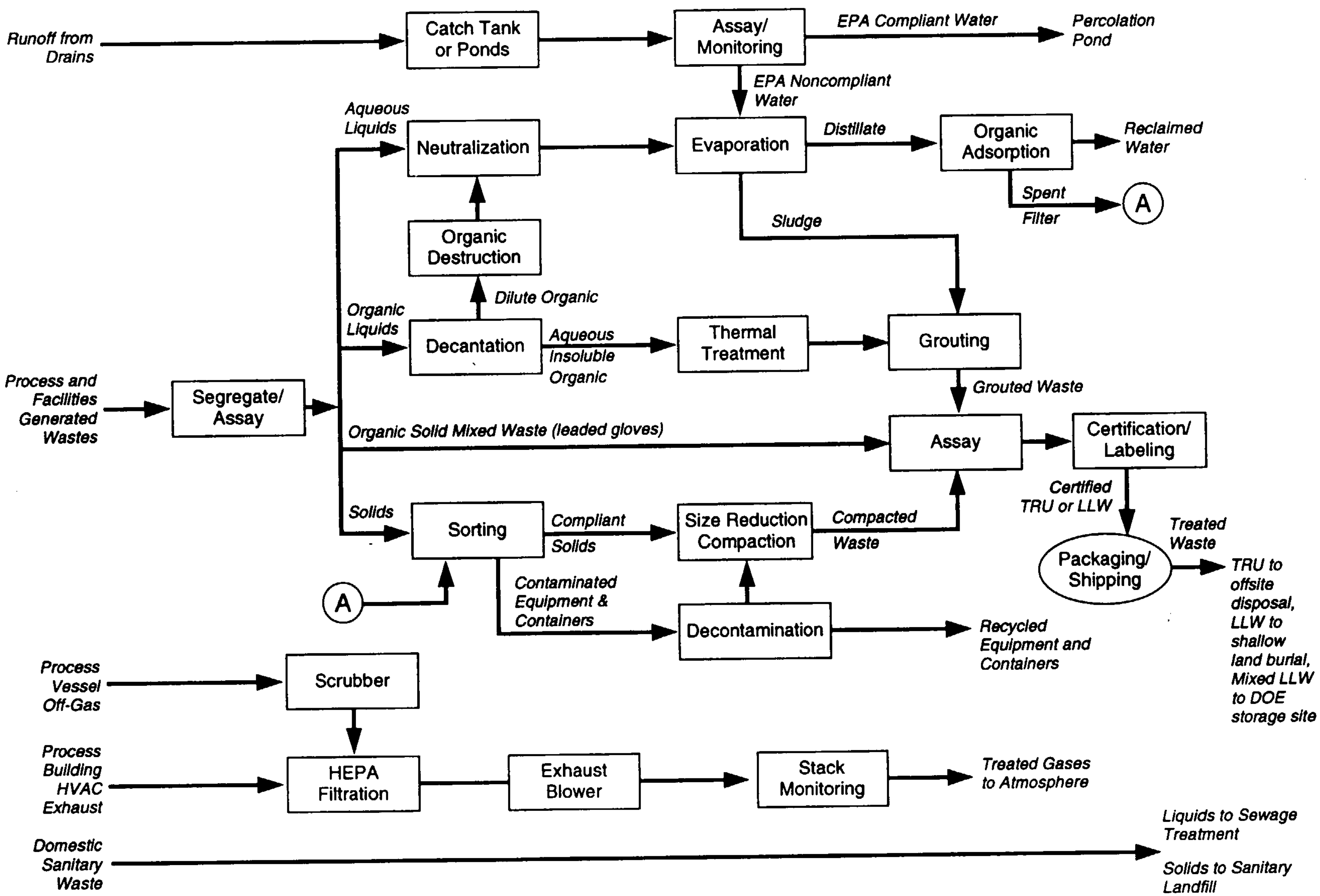
Nonhazardous (Sanitary) Waste. Nonhazardous sanitary liquid wastes generated in the facility would be transferred to a sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, would be hauled to a permitted sanitary landfill for disposal.

Nonhazardous (Other) Waste. Other nonhazardous liquid wastes generated from facilities support operations (for example, cooling system blowdown and evaporator condensate) would be collected in a catch tank and sampled before being reclaimed for recycle use or release to the environment. The facility design includes stormwater retention ponds with the necessary NPDES monitoring equipment. Runoff within the main facility area would be collected separately, and routed to the stormwater collection ponds, and then sampled and analyzed before discharge to the natural drainage channels (dry site) or river (wet site). If the runoff was contaminated, it would be treated in the process wastewater treatment system. Runoff outside of the main facility area would be discharged directly into the natural drainage channels or river.

Table E.3.3.5–1. Estimated Waste Volumes for the Ceramic Immobilization Alternative

Category	Annual Average Volume Generated From Construction (m^3)	Annual Volume Generated From Operations (m^3)	Annual Volume Effluent From Operations (m^3)
Transuranic			
Liquid	None	75[a]	None
Solid	None	99	99
Mixed Transuranic			
Liquid	None	None	None
Solid	None	0.7	0.7
Low-Level			
Liquid	None	7[a]	None
Solid	None	14	11
Mixed Low-Level			
Liquid	None	None	None
Solid	None	0.15	0.15
Hazardous			
Liquid	13	38	38
Solid	15	19	19
Nonhazardous (Sanitary)			
Liquid	22,000	34,000[b]	34,000[b]
Solid	Included in liquid	920	920
Nonhazardous (Other)			
Liquid	157,000[c]	170,000[d]	170,000[d]
Solid	108[e]	15[f]	None

[a] Liquid TRU waste and LLW would be treated with the remaining TRU and low-level sludge being solidified.
[b] Includes sewage and industrial wastewater.
[c] Includes service water, concrete batch plant water, and stormwater runoff.
[d] Includes industrial wastewater, cooling water blowdown, process wastewater, and stormwater runoff.
[e] Includes 162 t of construction material (assuming 1500 kg/m^3).
[f] Recyclable wastes.
Source: LLNL 1996d.



Source: LLNL 1996d.

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Figure E.3.3.5–1. Ceramic Immobilization Alternative—Waste Management Process Flow Diagram.

E.3.3.6 Electrometallurgical Treatment Alternative (Glass-Bonded Zeolite)

The design of the electrometallurgical treatment facility would place great emphasis on the minimization of both solid and liquid wastes. Where generation of a waste could not be avoided, methods would be pursued to recycle the waste. In general terms, waste management at the electrometallurgical treatment facility would include waste handling and treatment operations for processing the wastes generated by electrometallurgical treatment in aqueous, organic liquid, or solid form operations or by related site activities.

Table E.3.3.6–1 presents the estimated incremental annual waste volumes for the Pu disposition mission during construction and operation of the electrometallurgical treatment facility. Waste management capabilities would be provided to monitor, treat, and handle radioactive, industrial, and chemical wastes, as well as sanitary and stormwater wastes. The treated effluent from utility, process, and sanitary wastewater treatment would be reclaimed to be used as makeup to the cooling system. Other wastes generated by operations would include TRU, low-level, mixed, hazardous, and nonhazardous wastes. Management facilities for radioactive and nonradioactive waste would be located onsite.

The electrometallurgical treatment facility would utilize the waste treatment and management capabilities at INEL outlined in Appendix E.2.3. The waste treatment processes would include assay examination, sorting, separation, concentration, size reduction, special treatment, and thermal treatment. The wastes would be converted to water meeting effluent standards, grouted cement, or compacted solid waste as final form products for disposal. The waste treatment processing would also perform equipment and waste container decontamination operations.

Wastes would be generated during each step of the electrometallurgical treatment process and would be addressed under existing INEL waste operations requirements. The waste management process would involve the collecting, assaying, sorting, treating, packaging, storing, and shipping of radioactive, hazardous, and mixed wastes from Pu disposition operations, and hazardous and nonhazardous wastes from the support facilities.

Initial sorting of solid wastes would be performed at the generation source. Solid wastes would be treated by a variety of processes to ensure compliance with all applicable requirements. Solid LLW would be treated/ disposed of onsite at the Waste Experimental Reduction Facility and the RWMC. Waste products would be immobilized and packaged to meet DOT and DOE requirements. Liquid and solid organic wastes would be separated and dispositioned. The small quantity of mixed LLW would be managed in accordance with the *INEL Site Treatment Plan* that was developed to comply with the *Federal Facility Compliance Act* until a decision is made to allow disposal as radioactive waste following appropriate treatment. Mixed TRU wastes would be handled like other TRU wastes. Finally, nonhazardous, nonradioactive solid waste, and aqueous and gaseous wastes would be treated in conformance with standard industrial practice and regulatory requirements. Solid nonhazardous wastes would either be disposed of at a sanitary landfill or sent to a commercial recycle center.

Nonradioactive liquid wastes would be monitored, collected, and appropriately treated, if necessary, before discharge to the environment. Facilities would be provided to treat chemically contaminated wastewaters before discharge to the environment. Holding tanks would be provided for the wastes. Nonradioactive solid wastes would be recycled, where possible or transferred to approved disposal sites in accordance with accepted industrial practices.

All fire sprinkler water discharged in process areas during and after a fire would be contained, monitored, sampled, and if required, treated prior to disposal. Utility wastewater discharges (including cooling system and boiler blowdown) would be treated in an industrial waste pond.The facility would use the ANL-W onsite sanitary treatment system (sewage lagoons) to treat liquid sanitary wastes.

High-Level Waste. The electrometallurgical treatment facility would not generate an HLW waste stream from processing plutonium. However, the facility would produce an immobilized glass-bonded zeolite (GBZ)

product. The Pu disposition mission would produce 37 m^3 (49 yd^3) of immobilized GBZ product annually (LLNL 1996b:7-3). This immobilized glass-bonded zeolite product would require interim storage until a final disposal option becomes available.

Transuranic Waste. TRU wastes would be generated from process and facility operations, equipment decontamination, failed equipment, and used tools. Numerous processes, including those directly supporting the electrometallurgical treatment operations and those managing the various waste streams, would produce used ventilation air filters and Pu oxide sweepings, as well as contaminated operator clothing, gloves, gloveboxes, tools, wipes and rags, shoe covers, and other process equipment. Following characterization, these wastes would be handled, treated, and disposed of according to their level of contamination. If characterized as TRU waste, they would be appropriately treated and stored until final disposal (assumed to be WIPP).

Transuranic wastes would be treated, as appropriate, at the INEL Radioactive Scrap and Waste Facility to form grout or a compact solid waste. Treated TRU waste products would be packaged, assayed, and certified to meet the waste acceptance criteria of the WIPP or alternative treatment level. Assuming WIPP is determined to be a suitable repository for these wastes and depending on decisions made in the ROD associated with the supplemental EIS being prepared for the proposed continued phased development of WIPP for disposal of TRU waste, pursuant to the requirements of 40 CFR 191 and 40 CFR 268, these wastes would be transported to WIPP for disposal.

Mixed Transuranic Waste. A very small quantity of solid mixed TRU waste, mainly protective clothing and radiological survey waste, would be generated annually during operations. This mixed TRU waste primarily would be generated from activities at the waste handling/management facilities. Mixed TRU would be packaged for temporary storage, pending final treatment and disposal in accordance with the *INEL Site Treatment Plan* that was developed to comply with the *Federal Facility Compliance Act*. Current plans call for disposal at WIPP.

Low-Level Waste. LLW would be generated from numerous operations at the facility and would be treated by sorting, separation, concentration, and size-reduction processes. The Waste Experimental Reduction Facility could be utilized. Numerous processes, including those directly supporting the electrometallurgical treatment operations and those managing the various waste streams, would produce contaminated operator clothing, gloves, tools, wipes and rags, shoe covers, and process equipment. Following characterization, these wastes would be handled, treated, and disposed of according to their level of contamination. Final LLW products would be surveyed and transported within the INEL site for shallow land burial at the LLW disposal pits at the RWMC. Any contaminated washdown water would be treated and solidified in the Radioactive Liquid Waste Treatment Facility.

Mixed Low-Level Waste. A very small quantity of solid mixed LLW, mainly protective clothing and radiological survey waste, would be generated annually during operations. This mixed LLW primarily would be generated from activities at the waste handling/management facilities. Any mixed LLW would be stored onsite on an interim basis until treatment, disposal, or offsite shipment in accordance with the *INEL Site Treatment Plan* that was developed to comply with the *Federal Facility Compliance Act*.

Hazardous Waste. Hazardous wastes would consist of chemical makeup and reagents for support activities, and lubricants and oils for process and support equipment. Solid hazardous wastes would include lead packing, and used wipes and rags contaminated with oils, lubricants, and cleaning solvents. Liquid hazardous wastes generated from the facility would include cleaning solvents, vacuum pump oils, film processing fluids, hydraulic fluids from mechanical equipment, antifreeze solutions, and paint. The liquid and solid hazardous waste would be collected at the facility and stored on an interim basis. The hazardous wastes would be recycled, where appropriate, or stored and packaged for offsite treatment or disposal at an RCRA-permitted facility in accordance with ongoing waste management procedures at INEL.

Nonhazardous (Sanitary) Waste. Nonhazardous sanitary liquid wastes generated in the facility would be treated in the existing ANL-W sanitary waste system. Nonhazardous solid wastes, such as domestic trash and office waste, would be hauled to a permitted sanitary landfill for disposal.

Nonhazardous (Other) Waste. Other nonhazardous liquid wastes generated from facilities support operations (for example, cooling system blowdown and evaporator condensate) would be collected in a catch tank and sampled before being reclaimed for recycle use or release to the environment. The facility design includes stormwater retention ponds with the necessary monitoring equipment. Runoff within the main facility area would be collected separately, routed to the stormwater collection ponds, and then sampled and analyzed before discharge to the natural drainage channels. If the runoff was contaminated, it would be treated in the process wastewater treating system. Runoff outside of the main facility area would be discharged directly into the natural drainage channel.

Table E.3.3.6–1. Estimated Waste Volumes for Electrometallurgical Treatment Alternative

Category	Annual Average Volume Generated From Modification of Electrometallurgical Treatment Facility[a] (m^3)	Annual Volume Generated by Electrometallurgical Treatment Facility (m^3)	Total Annual Volume Effluent From Electrometallurgical Treatment Facility (m^3)
Transuranic			
Liquid	None	None	None
Solid	None	6	6
Mixed Transuranic			
Liquid	None	None	None
Solid	None	0.8	0.8
Low-Level			
Liquid	None	2	None
Solid	None	55	55
Mixed Low-Level			
Liquid	None	None	None
Solid	None	0.8	0.8
Hazardous			
Liquid	None	None	None
Solid	None	0.8	0.8
Nonhazardous (Sanitary)			
Liquid	2,780	1,550	None
Solid	5,730	1,500	1,500
Nonhazardous (Other)			
Liquid	2,840	2,990[b]	None
Solid	0.4	0.8[c]	None

[a] Quantity generated to modify facility to accommodate Pu disposition mission.
[b] Includes 0.38 m^3 of recyclable wastes, and cooling system blowdown and wastewater from plant activities.
[c] Recyclable wastes.
Source: LLNL 1996b.

E.3.3.7 Evolutionary Light Water Reactor Alternative

The solid and liquid nonhazardous wastes generated during construction would include concrete and steel waste materials and sanitary wastewater. The steel waste would be recycled as scrap before completing construction. The remaining nonhazardous wastes would be disposed of as part of the construction project by the contractor. Uncontaminated wastewater would be used for soil compaction and dust control, and excavated soil would be used for grading and site preparation. Wood, paper, and metal wastes would be shipped offsite to a commercial contractor for recycling. Hazardous construction wastes would consist of adhesives, oils, cleaning fluids, solvents, and coatings. This waste would be packaged in DOT-approved containers and shipped offsite to commercial RCRA-permitted treatment, storage, and disposal facilities. No radioactive waste would be generated during construction.

The reactor design considers and incorporates waste minimization and pollution prevention. Activities that generate radioactive and hazardous wastes would be segregated, where possible, to avoid the generation of mixed wastes. Where applicable, treatment to separate radioactive and nonradioactive components would reduce the volume of mixed wastes and permit for cost-effective disposal or recycle. To facilitate waste minimization, where possible, nonhazardous materials would be substituted for those materials that contribute to the generation of hazardous or mixed waste. Production processes would be configured with minimization of waste production given high priority. Where possible, material from the waste streams would be treated to facilitate disposal as nonhazardous wastes. Future D&D considerations have also been incorporated into the design.

Tables E.3.3.7–1 and E.3.3.7–2 present the estimated annual spent nuclear fuel and waste volumes during construction and operation of large and small evolutionary light water reactors (LWRs). Liquid and solid waste streams are routed to the waste management system. Figures E.3.3.7–1 and E.3.3.7–2 depict the waste management systems. Solid wastes would be characterized and segregated into LLW, hazardous, and mixed wastes, then treated to a form suitable for disposal or storage within the facility. Liquid wastes would be treated onsite to reduce hazardous/toxic and radioactive elements before discharge or transport. All fire sprinkler water discharged in process areas would be contained and treated as process wastewater, when required.

Spent Nuclear Fuel. Spent nuclear fuel would not be reprocessed. Fuel elements containing spent fuel would be stored for 3 to 10 years in water-cooled storage basins. The spent fuel storage pool must be able to accommodate fuel assemblies for 10 years after reactor discharge. The spent fuel pool would be equipped with an underwater canister loading system. Twelve spent fuel assemblies would be placed in fixed positions in a borated aluminum or stainless-steel basket for criticality safety. The basket would be contained in a canister with seal-welded lids. After the 10-year cooling period, the canisters would be drained, vacuum dried, and backfilled with helium through lid penetrations in preparation for dry storage. The canisters would be transferred in a cask to the interim spent fuel storage facility. At the storage facility each canister would be transferred to its final storage cask, which would be made of precast concrete. Casks would be placed on a concrete basemat. Periodic visual inspections of the canisters and the cask vents would be required. Periodic testing for helium leaks might also be required. The facility design would have sufficient capacity to store the spent nuclear fuel for the life of the facility, pending the availability of a geologic repository.

High-Level Waste. Under the assumption of no fuel reprocessing, the evolutionary LWR would not generate any HLW.

Transuranic Waste. Under the assumption of no fuel reprocessing, the evolutionary LWR would not generate any TRU waste.

Low-Level Waste. LLW would be generated by the operation of the reactor and support facilities and would include concentrated waste from the condensate demineralizer system. Process effluents would be temporarily stored in tanks before conversion into a solid LLW that is suitable for disposal. The liquid effluent would be

discharged through a permitted NPDES outfall. The bulk of the solid LLW, consisting of contaminated equipment pieces, plastic sheeting, and protective clothing, would be generated from reactor operations. Solid LLW would be compacted, if appropriate, and then disposed of at a DOE-approved onsite or offsite disposal facility.

Mixed Low-Level Waste. Very small amounts of liquid mixed LLW would be generated by reactor operations. Solid mixed LLW could consist of wipes laden with contaminated oils, lubricants, and solvents used to decontaminate surfaces. Mixed LLW would be stored in an onsite RCRA-permitted storage facility until treatment in accordance with the site-specific site treatment plan that was developed to comply with the *Federal Facility Compliance Act*.

Hazardous Waste. Liquid hazardous wastes would consist of cleaning solvents, cutting oils, vacuum pump oils, film processing fluids, hydraulic fluids from mechanical equipment, antifreeze solutions, and paint. A cleaning solvent would be selected from a list of nonhalogenated solvents. Liquid hazardous wastes would be collected in DOT-approved containers and sent to an onsite hazardous waste accumulation area. The accumulation area would provide a 90-day staging capacity prior to shipment in DOT-certified transportation to an offsite commercial RCRA-permitted treatment, storage, and disposal facility. Solid hazardous wastes would be generated from nonradioactive materials such as wipes contaminated with oils, lubricants, and cleaning solvents that would be used for equipment outside the main processing units. After compaction, if appropriate, the solid hazardous wastes would be packaged in DOT-approved containers and sent to a hazardous waste accumulation area for staging prior to shipment in DOT-certified transporters to an offsite commercial RCRA-permitted treatment, storage, and disposal facility.

Nonhazardous (Sanitary) Waste. Sewage wastewater would be treated in the sanitary wastewater treatment plant, site septic systems, or pretreated prior to discharge to existing municipal systems. Sewage wastewater would be kept separate from all industrial and process wastewaters and normally would contain no radioactive wastes from the reactor facility. The sewage wastewater would be routinely monitored for radioactive contaminants. The sludge would be disposed of in a permitted landfill. The treated effluent would be discharged through a permitted NPDES outfall (wet site) or recycled for cooling water makeup and other services (dry site). The treated effluent from the process wastewater treatment would be discharged to the river through an NPDES outfall (wet site) or a natural drainage channel (dry site). Other nonrecyclable, nonhazardous solid sanitary and industrial wastes would be compacted and disposed of in a permitted landfill.

Nonhazardous (Other) Waste. The reactor design includes stormwater retention facilities with the necessary NPDES monitoring equipment. Runoff within the Limited Area and Protected Area would be collected separately, routed to the stormwater collection ponds and then sampled and analyzed before discharge to the natural drainage channels (dry site) or river (wet site). If the runoff was contaminated, it would be treated in the radioactive waste treatment system. Runoff from the Property Protection Area would be discharged directly into the natural drainage channels or river. Cooling tower blowdown would be treated and discharged to the river (wet site) or recycled for reuse (dry site). The treated effluent from the utility wastewater treatment would be discharged to the river through an NPDES outfall (wet site) or a natural drainage channel (dry site). All sludges would be disposed of in a permitted landfill.

Table E.3.3.7–1. Estimated Spent Nuclear Fuel and Waste Volumes for the Evolutionary Light Water Reactor (Large) Alternative[a]

Category	Yearly Average Volume Generated From Construction (m^3)	Annual Volume Generated From Operations, Dry Site (m^3)	Annual Volume Effluent From Operations, Dry Site (m^3)	Annual Volume Generated From Operations, Wet Site (m^3)	Annual Volume Effluent From Operations, Wet Site (m^3)
Spent Nuclear Fuel	None	10[b]	10b	10b	10b
Low-Level					
Liquid	None	18,900[c]	None	18,900[c]	None
Solid	None	500	70	500	70
Mixed Low-Level					
Liquid	None	None	None	None	None
Solid	None	5	5	5	5
Hazardous					
Liquid	Included in solid	Included in solid	Included in solid	Included in solid	Included in solid
Solid	711	27	27	27	27
Nonhazardous (Sanitary)					
Liquid	102,000	342,000	341,000	23,900,000	23,800,000[d]
Solid	11,500	5,280	1,760[e]	5,280	1,760[e]
Nonhazardous (Other)					
Liquid	1,890[f]	Included in sanitary	Included in sanitary	Included in sanitary	Included in sanitary
Solid	Included in sanitary	4,430[g]	None	4,430[g]	None

[a] Waste volumes are per reactor. Disposition mission would require two reactors.

[b] Spent fuel per reactor per year; total spent fuel for disposition mission (two reactors) would be 337 m3. Residual heavy metal content in spent nuclear fuel would be 38.2 t per reactor per year. Total for disposition mission would be 1,300 t.

[c] Liquid LLW would be treated with the remaining LLW sludge being solidified.

[d] For the evolutionary LWR, Hanford is considered to be a wet site. However, the only liquid discharge would be from cooling tower blowdown and is estimated to be 23,470,000 m^3. All other wastewater would be recycled.

[e] Assumes overall compaction factor of 3:1.

[f] Does not include groundwater dewatering, if required.

[g] Recyclable wastes.

Source: DOE 1995f; LLNL 1996g.

Table E.3.3.7–2. Estimated Spent Nuclear Fuel and Waste Volumes for the Evolutionary Light Water Reactor (Small) Alternative[a]

Category	Yearly Average Volume Generated From Construction (m^3)	Annual Volume Generated From Operations, Dry Site (m^3)	Annual Volume Effluent From Operations, Dry Site (m^3)	Annual Volume Generated From Operations, Wet Site (m^3)	Annual Volume Effluent From Operations, Wet Site (m^3)
Spent Nuclear Fuel	None	5[b]	5[b]	5[b]	5[b]
Low-Level					
Liquid	None	2,990[c]	None	2,990[c]	None
Solid	None	270	40	270	40
Mixed Low-Level					
Liquid	None	None	None	None	None
Solid	None	5	5	5	5
Hazardous					
Liquid	Included in solid	Included in solid	Included in solid	Included in solid	Included in solid
Solid	650	27	27	27	27
Nonhazardous (Sanitary)					
Liquid	56,800	190,000	189,000	11,000,000	11,000,000[d]
Solid	7,650	3,210	1,070[e]	3,210	1,070[e]
Nonhazardous (Other)					
Liquid	1,890[f]	Included in sanitary	Included in sanitary	Included in sanitary	Included in sanitary
Solid	Included in sanitary	2,680[g]	None	2,680[g]	None

[a] Waste volumes are per reactor. Disposition mission would require four reactors.

[b] Spent fuel per reactor per year; total spent fuel for disposition mission (four reactors) would be 338 m^3. Residual heavy metal content in spent nuclear fuel would be 17.7 t per reactor per year. Total for disposition would be 1,200 t.

[c] Liquid LLW would be treated with the remaining LLW sludge being solidified.

[d] For the evolutionary LWR, Hanford is considered to be a wet site. However, the only liquid discharge would be from cooling tower blowdown and is estimated to be 10,600,000 m^3. All other wastewater would be recycled.

[e] Assumes overall compaction factor of 3:1.

[f] Does not include groundwater dewatering, if required.

[g] Recyclable wastes.

Source: DOE 1995f; LLNL 1996g.

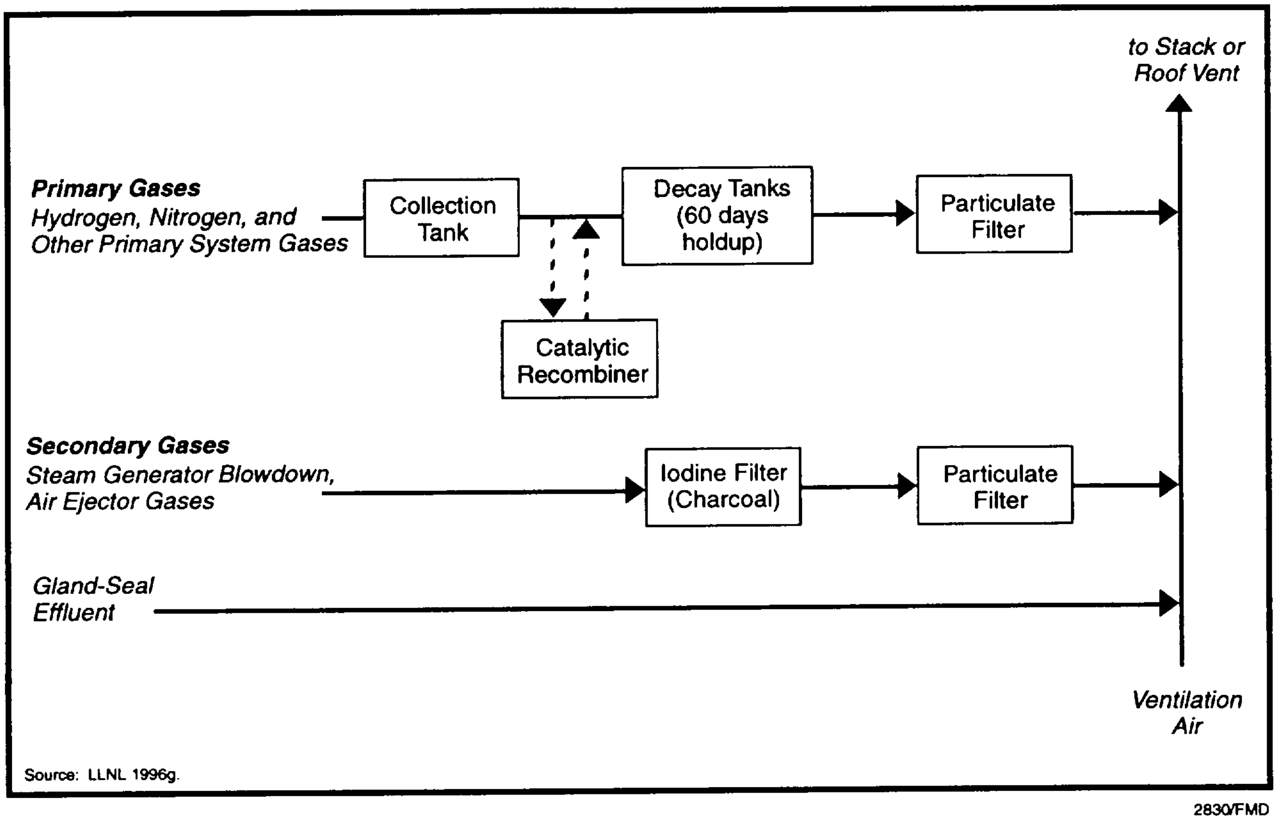


Figure E.3.3.7–1. Evolutionary Light Water Reactor Alternative—Gaseous Waste Management Process Flow Diagram.

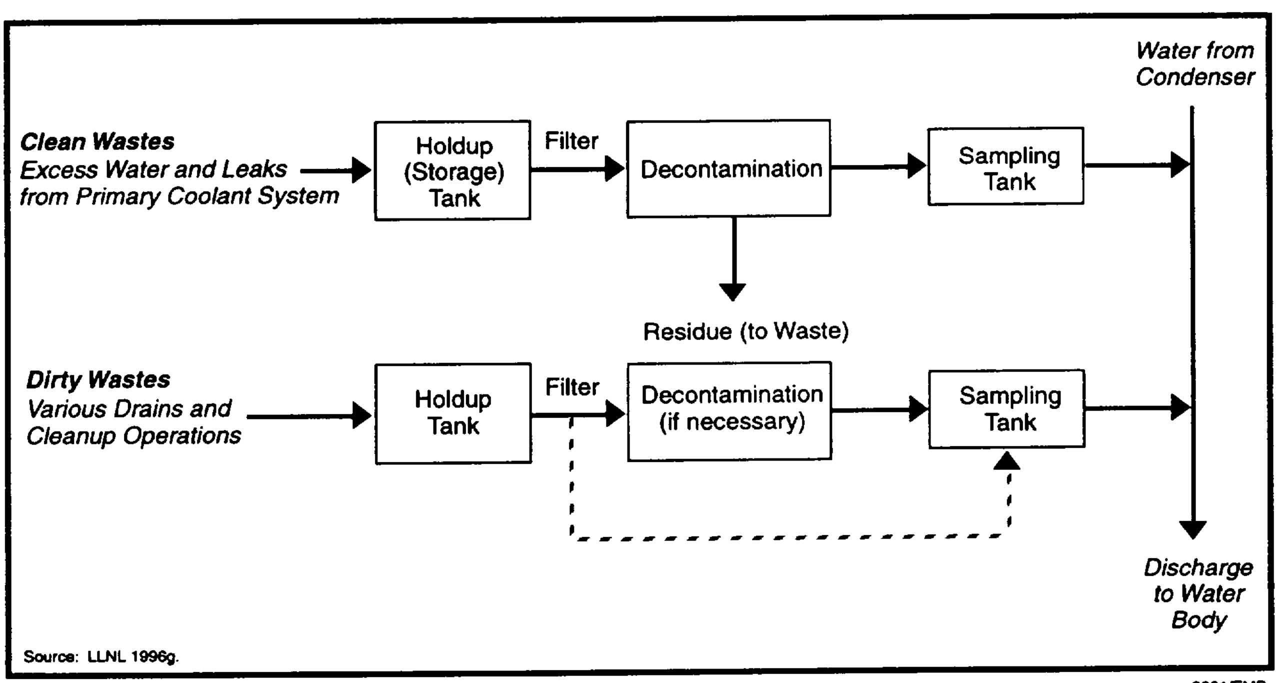


Figure E.3.3.7–2. Evolutionary Light Water Reactor Alternative—Liquid Waste Management Process Flow Diagram.

Appendix F
Air Quality and Noise

F.1 AIR QUALITY

This appendix provides detailed data that support air quality impact assessments addressed in Chapter 3, Affected Environment-Air Quality and Chapter 4, Environmental Consequences-Air Quality. The data presented include emission inventories for site-related activities and facility emissions for various alternatives. Section F.1.1 presents the methodology and models used in the air quality assessment. Section F.1.2 presents supporting data applicable to each site. Sections F.1.2.2 through F.1.2.9 contain tables of site-specific information applicable to the air quality assessments at each site and figures showing wind rose data specific to each site. Section F.1.3 presents the emission rates for the facilities considered for each alternative. Section F.2 presents sound level monitoring data for each site and summarizes relevant local noise regulations.

F.1.1 METHODOLOGY AND MODELS

The assessment of potential impacts to air quality is based upon comparison of proposed project effects with applicable standards and guidelines. The Industrial Source Complex Short-Term Model Version 2 (ISCST2) is used to estimate concentrations of pollutants from emission sources at each site. The screening model (SCREEN2) is used to estimate concentrations of pollutants at the site boundary for the generic sites, assuming a distance to the site boundary of 800 meters (m) (0.5 miles [mi]).

The air quality modeling analysis performed for the candidate sites is considered a "screening level" analysis. It applies conservative assumptions to each site to permit comparison among the sites of the impacts associated with the respective alternatives. These conservative assumptions will tend to overestimate pollutant concentrations at each site.

The assumptions applied to the air quality analysis at each site are as follows: where available, existing modeling analyses of criteria pollutant and toxic/hazardous pollutant emissions were used to determine No Action concentrations and are based on actual source locations and stack parameters; criteria pollutant and toxic/hazardous pollutant emissions were modeled for other sites and each alternative from a single source centrally located within the complex of facilities on each site assuming a 10-m (32.8-foot [ft]) stack height, a 0.3-m (1-ft) stack diameter, stack exit temperature equal to ambient temperature, and a stack exit velocity equal to 0.03 m/second (s) (0.1 ft/s) unless otherwise specified. These assumptions will tend to overestimate pollutant concentrations because they do not account for spacial and temporal variations of emission sources.

Emission sources at each facility or site and for each alternative were assumed to be in the same location as existing toxic/hazardous pollutant emission sources and assumed the modeling parameters used for those emissions.

The ISCST2 model is a revision of the ISCST model. The modeling algorithms have not been changed and the revised model will give nearly identical results to the original ISCST model for most applications. The performance of the ISCST model has not been validated with field data. However, it is an extended version of a single-stack model, CRSTER, that has been examined using field data from four large power plants. The performance of the ISCST model has been evaluated with field data for its point source submodel and for its special features, such as the gravitational settling/dry deposition option and building downwash option. From the validation studies for the single source CRSTER model, based on field data measured at four large power plants, it was concluded that the model acceptably predicts the upper percentile of the corresponding distributions of 1-hour concentrations and of the corresponding distributions of 24-hour concentrations. The highest-second-highest (a term within the model to represent the second highest concentration) 1-hour

concentrations were predicted within a factor of two at two-thirds of the field sampling sites for elevated power plant plumes. The ratio of highest-second-highest 24-hour concentration to measured concentration ranged from about 0.2 to 2.7 at about 90 percent of the sampling sites.

In other validation studies for the point source model, the CRSTER model predicted peak short-term (1-, 3-, and 24-hour) concentration values within 30 to 70 percent at a plain site (EPRI 1983a:7-1–7-7). The CRSTER model predicted peak 1-hour concentrations within 2 percent and underpredicted peak 3-hour concentrations by about 30 percent at a moderately complex terrain site (EPRI 1985a:7-1). The ISCST model overpredicts 1-hour concentrations by about 60 percent with better predictions for longer time periods at an urban site (EPRI 1988a:5-2). Uses of gravitational settling/dry deposition and building downwash options were found to improve the model performance significantly over that of the model without such features (APCA 1986a:258-264; EPA 1981a:5-1,5-2; EPA 1982a:151,152).

F.1.2 SUPPORTING DATA

F.1.2.1 Overview

This section presents supporting information for each of the eight existing DOE sites considered under the No Action Alternative, and the various storage and disposition alternatives, as appropriate. Table F.1.2.1–1 presents the air quality standards applicable to each site. Subsequent sections present supporting information used in the air quality analysis at the Hanford Site (Hanford), Nevada Test Site (NTS), Idaho National Engineering Laboratory (INEL), Pantex Plant (Pantex), Oak Ridge Reservation (ORR), Savannah River Site (SRS), Rocky Flats Environmental Technology Site (RFETS), and Los Alamos National Laboratory (LANL).

F.1.2.2 Hanford Site

This section provides information on climatology and meteorology, modeling assumptions, atmospheric dispersion characteristics, and annual mean windspeeds and direction frequencies at Hanford.

Climatology and Meteorology. Figure F.1.2.2–1 shows annual mean windspeeds and wind direction frequencies for July 1989 through June 1990 measured at the 10-m (32.8-ft) level of the Hanford Meteorology Station. The wind rose shows that the maximum wind direction frequency for 1989-1990 is from the west-northwest. The mean windspeed from the west-northwest is 4.3 m/s (9.6 miles per hour [mph]); the maximum mean windspeed is 5 m/s (11.2 mph) from the west-southwest. The historical wind data from the site indicate that the prevailing wind direction is from the west-northwest. The average annual windspeed is 3.4 m/s (7.6 mph) (HF PNL 1994b:83-84).

The average annual temperature is 11.8 degrees Celsius (°C) (53.3 degrees Fahrenheit [°F]); average monthly temperatures vary from a minimum of -1.5 °C (29.3 °F) in January to a maximum of 24.7 °C (76.5 °F) in July (HF PNL 1994b:83-84).

The average annual precipitation at Hanford is 16.0 centimeters (cm) (6.3 inches (in) (HF PNL 1994b:83-84).

Topographic features have a significant impact on the climate of Hanford. All air masses that reach the region undergo some modification resulting from their passage over the complex topography of the Pacific Northwest. The climate of the region is strongly influenced by the Pacific Ocean and the Cascade Range to the west and by the Rocky Mountains to the east and the north. The Rocky Mountains play a key role in protecting the region from the severe winter storms and extremely low temperatures associated with modified arctic air masses that move southward through Canada.

The Hanford Meteorological Station's climatological summary and the National Severe Storms Forecast Center's database list only 24 tornado occurrences within 161 kilometers (km) (100 mi) of Hanford from 1916 to 1994.

Table F.1.2.1–1. Ambient Air Quality Standards Applicable to Existing Department of Energy Sites

Pollutant	Averaging Time	Primary NAAQS[a] (μg/m³)	Secondary NAAQS[a] (μg/m³)	Washington (Hanford) (μg/m³)	Nevada (NTS) (μg/m³)	Idaho (INEL) (μg/m³)	Texas (Pantex) (μg/m³)	Tennessee (ORR) (μg/m³)	Georgia and South Carolina (SRS) (μg/m³)	Colorado (RFETS) (μg/m³)	New Mexico (LANL) (μg/m³)
Criteria Pollutants											
Carbon monoxide	8-hour	10,000	b	10,000	10,000	10,000	10,000	10,000	10,000	10,000	7,689[c]
	1-hour	40,000	b	40,000	40,000	40,000	40,000	40,000	40,000	40,000	11,578[c]
Lead	Calendar quarter	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	24-hour	b	b	0.5	b	b	b	b	b	b	b
Nitrogen dioxide	Annual	100	100	100	100	100	100	100	100	100	73[c]
	24-hour	b	b	b	b	b	b	b	b	b	145[c]
Ozone	1-hour	235	235	235	235	235	235	235	235	235	235
Particulate matter less than or equal to 10 microns in diameter	Annual	50	50	50	50	50	50	50	50	50	50
	24-hour	150	150	150	150	150	150	150	150	150	150
Sulfur dioxide	Annual	80	b	52	80	80	80	80	80	80	40[c]
	24-hour	365	b	260	365	365	365	365	365	365	202[c]
	3-hour	b	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300
	3-hour	b	b	b	b	b	b	b	b	700[d]	b
	1-hour	b	b	1,018	b	b	b	b	b	b	b
	1-hour	b	b	655[e]	b	b	b	b	b	b	b
	30-minute	b	b	b	b	b	1,045	b	b	b	b

Table F.1.2.1–1. Ambient Air Quality Standards Applicable to Existing Department of Energy Sites—Continued

Pollutant	Averaging Time	Primary NAAQS[a] (μg/m³)	Secondary NAAQS[a] (μg/m³)	Washington (Hanford) (μg/m³)	Nevada (NTS) (μg/m³)	Idaho (INEL) (μg/m³)	Texas (Pantex) (μg/m³)	Tennessee (ORR) (μg/m³)	Georgia and South Carolina (SRS) (μg/m³)	Colorado (RFETS) (μg/m³)	New Mexico (LANL) (μg/m³)
State and County Mandated Pollutants											
Beryllium	24-hour	b	b	b	b	b	0.01	b	b	b	b
Gaseous fluoride	30-day	b	b	0.8	b	b	0.8	1.2	0.8	b	b
	7-day	b	b	1.7	b	b	1.6	1.6	1.6	b	b
	24-hour	b	b	2.9	b	b	2.9	2.9	2.9	b	b
	12-hour	b	b	3.7	b	b	3.7	3.7	3.7	b	b
	8-hour	b	b	b	b	b	b	250	b	b	b
Hydrogen sulfide	1-hour	b	b	b	112	b	b	b	b	142	11[c]
	30-minute	b	b	b	b	b	111	b	b	b	b
Sulfuric acid	24-hour	b	b	b	b	b	15	b	b	b	b
	1-hour	b	b	b	b	b	50	b	b	b	b
Total reduced sulfur		b	b	b	b	b	b	b	b	b	3
Total suspended particulates	Annual	b	b	60	b	60	b	b	75	75	60[c]
	30-day	b	b	b	b	b	b	b	b	b	90[c]
	7-day	b	b	b	b	b	b	b	b	b	110[c]
	24-hour	b	b	150	b	150	b	150	b	150	150[c]
	3-hour	b	b	b	b	b	200	b	b	b	b
	1-hour	b	b	b	b	b	400	b	b	b	b

[a] The NAAQS (40 CFR 50), other than those for ozone, particulate matter, lead, and those based on annual averages, are not to be exceeded more than once per year. The ozone standard is attained when the expected number of days per year with maximum hourly average concentrations above the standard is ≤ 1. The 24-hour particulate matter standard is attained when the expected number of days with a 24-hour average concentration above the standard is ≤ 1. The annual arithmetic mean particulate matter standard is attained when the expected annual arithmetic mean concentration is less than or equal to the standard. The calendar quarter lead standard is not to be exceeded.

[b] There is no standard.

[c] State standard. The conversion from ppm to μg/m³ for the ambient air quality standard is calculated with the corrections for temperature (21 °C) and pressure (elevation) (7,400 ft mean sea level).

[d] State of Colorado also has an incremental standard for sulfur dioxide.

[e] The standard is not to be exceeded more than twice in any seven consecutive days.

Note: NAAQS=National Ambient Air Quality Standards; μg-microgram.

Source: 40 CFR 50; CO DPHE 1994a; ID DHW 1995a; ID DHW 1995b; ID DHW 1995c; NM EIB 1995a; NM EIB 1996a; NV DCNR 1995a; SC DHEC 1992b; TN DEC 1994a; TX NRCC 1992a; WA Ecology 1994a.

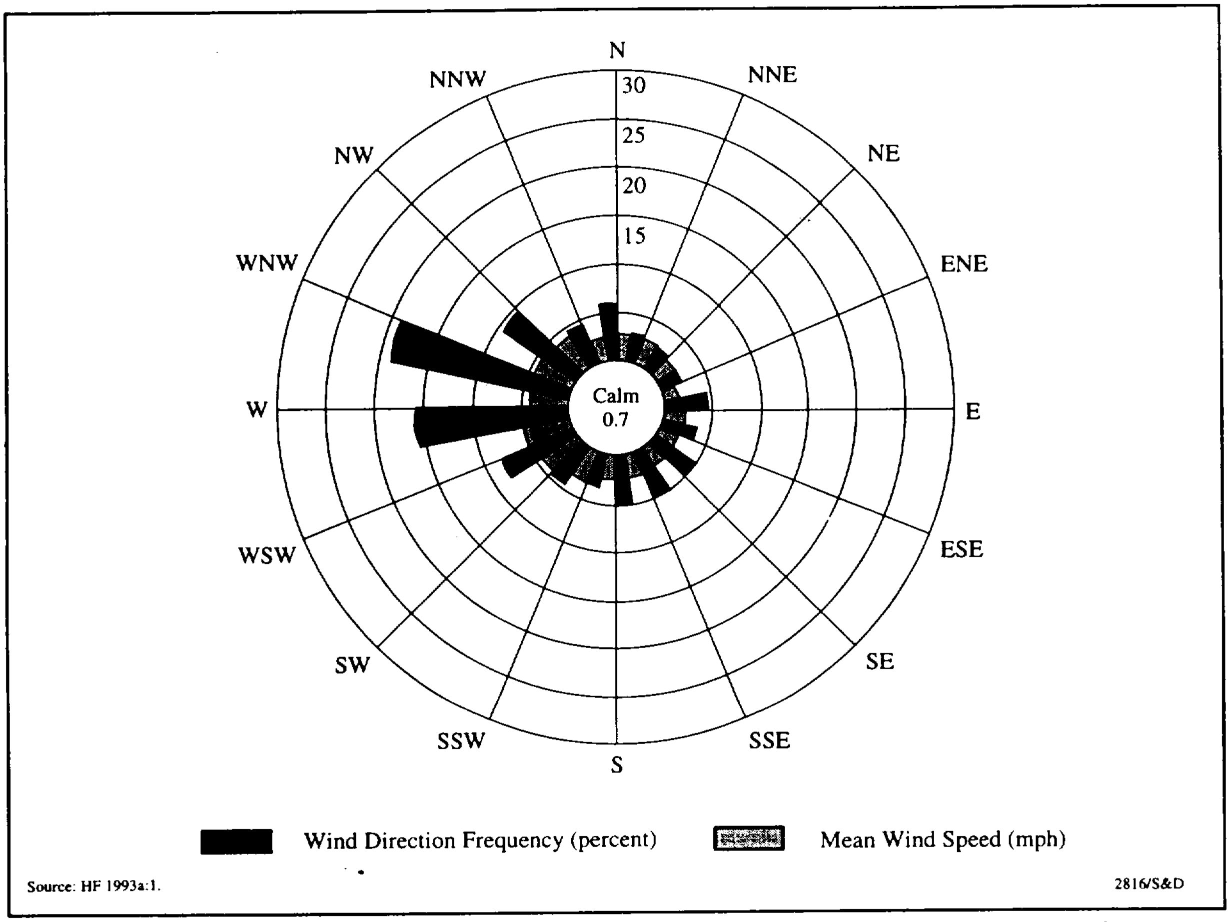


Figure F.1.2.2–1. Wind Distribution at Hanford Site, 1989-1990 (10-meter level).

Only one of these tornadoes was observed within the boundaries of Hanford (on its extreme western edge), and no damage resulted. The estimated probability of a tornado striking a point at Hanford is 9.6×10^{-6}/year (yr) (HF PNL 1994a:4.10). Because tornadoes are infrequent and generally small in the Pacific Northwest (and hurricanes do not reach this area), risks from severe winds are generally associated with thunderstorms or the passage of strong cold fronts. The greatest peak wind gust recorded at 15.2 m (50 ft) above ground level at the Hanford Meteorology Station was 36 m/s (80 mph). Observations indicate a return period of about 200 years for a peak gust in excess of 40 m/s (90 mph) at 15.2 m (50 ft) above ground level (HF PNL 1983a:V-2,V-13, XI-1).

Emission Rates. Table F.1.2.2–1 presents the emission rates for criteria and toxic/hazardous pollutants at Hanford. These emission rates were used as input into the ISCST2 model to estimate No Action pollutant concentrations.

Modeling Assumptions. In order to estimate maximum pollutant concentrations at or beyond the Hanford boundary, criteria pollutant emissions and toxic/hazardous pollutant emissions were modeled from a centrally located stack at a height of 10 m (32.8 ft), with a stack diameter of 0.3 m (1 ft), an exit velocity of 0.03 m/s (0.1 ft/s), and an exit temperature equal to ambient temperature.

Atmospheric Dispersion Characteristics. Data collected at Hanford meteorological monitoring station indicate that unstable conditions occur approximately 25 percent of the time, neutral conditions approximately 31 percent, and stable conditions approximately 44 percent, on an annual basis (HF 1993a:1).

Table F.1.2.2-1. Emission Rates of Criteria and Toxic/Hazardous Pollutants at Hanford Site[a]

Pollutant	Emission Rate (kg/yr)
Criteria Pollutants	
Carbon monoxide	11,660
Nitrogen dioxide	46,660
Particulate matter less than or equal to 10 microns in diameter[b]	4,566
Sulfur dioxide	200
Total suspended particulates[b]	4,566
Volatile organic compounds	927.8
Toxic/Hazardous Pollutants	
Ammonia	2.26

[a] For stationary sources within Hanford Site projected for 2005.
[b] Total suspended particulates emissions are assessed as particulate matter less than or equal to 10 microns in diameter.
Note: yr=year.
Source: HF 1995a:1.

F.1.2.3 Nevada Test Site

This section provides information on climatology and meteorology, modeling assumptions, atmospheric dispersion characteristics, and annual mean windspeeds and direction frequencies at NTS.

Climatology and Meteorology. Figure F.1.2.3–1 shows annual mean windspeeds and wind direction frequencies for 1991 measured at the 10-m (32.8-ft) level of the Desert Rock National Weather Service station. The wind rose shows that the maximum wind direction frequency for 1991 is from the northeast with a secondary maximum from the north-northeast. The mean windspeed from the northeast is 4.2 m/s (9.4 mph) and from the north-northeast it is 4.7 m/s (10.5 mph); the maximum mean windspeed is 6.3 m/s (14.1 mph) from the south-southwest.

Historical data indicate that predominating winds are southerly during summer and northerly during winter. The general downward slope in the terrain from north to south results in an intermediate scenario that is reflected in the characteristic diurnal wind reversal from southerly winds during the day to northerly winds at night. This north-to-south reversal is strongest in the summer and, on occasion, becomes intense enough to override the wind regime associated with large-scale pressure systems. Average annual windspeeds and direction vary with location. At higher elevations on Pahute Mesa, the average annual windspeed is 4.7 m/s (10.5 mph). The prevailing wind direction during winter months is north-northeasterly, and during summer months, winds are southerly. In Yucca Flat, the average annual windspeed is 3.1 m/s (7 mph). The prevailing wind direction during winter months is north-northwesterly and during summer months is south-southwesterly. At Mercury, Nevada, the average annual windspeed is 3.6 m/s (8 mph), with northwesterly prevailing winds during the winter months and southwesterly winds during the summer months (NT DOE 1993e:2-17,2-19).

Elevation influences temperatures on NTS. At an elevation of 2,000 m (6,560 ft) above mean sea level (MSL) on Pahute Mesa, the average daily maximum/minimum temperatures are 4.4/-2.2 °C (40/28 °F) in January and 26.7/16.7 °C (80/62 °F) in July. In Yucca Flat, 1,195 m (3,920 ft) above MSL, the average daily maximum/minimum temperatures are 10.6/-6.1 °C (51/21 °F) in January and 35.6/13.9 °C (96/57 °F) in July (NT DOE 1993e:2-17,2-19).

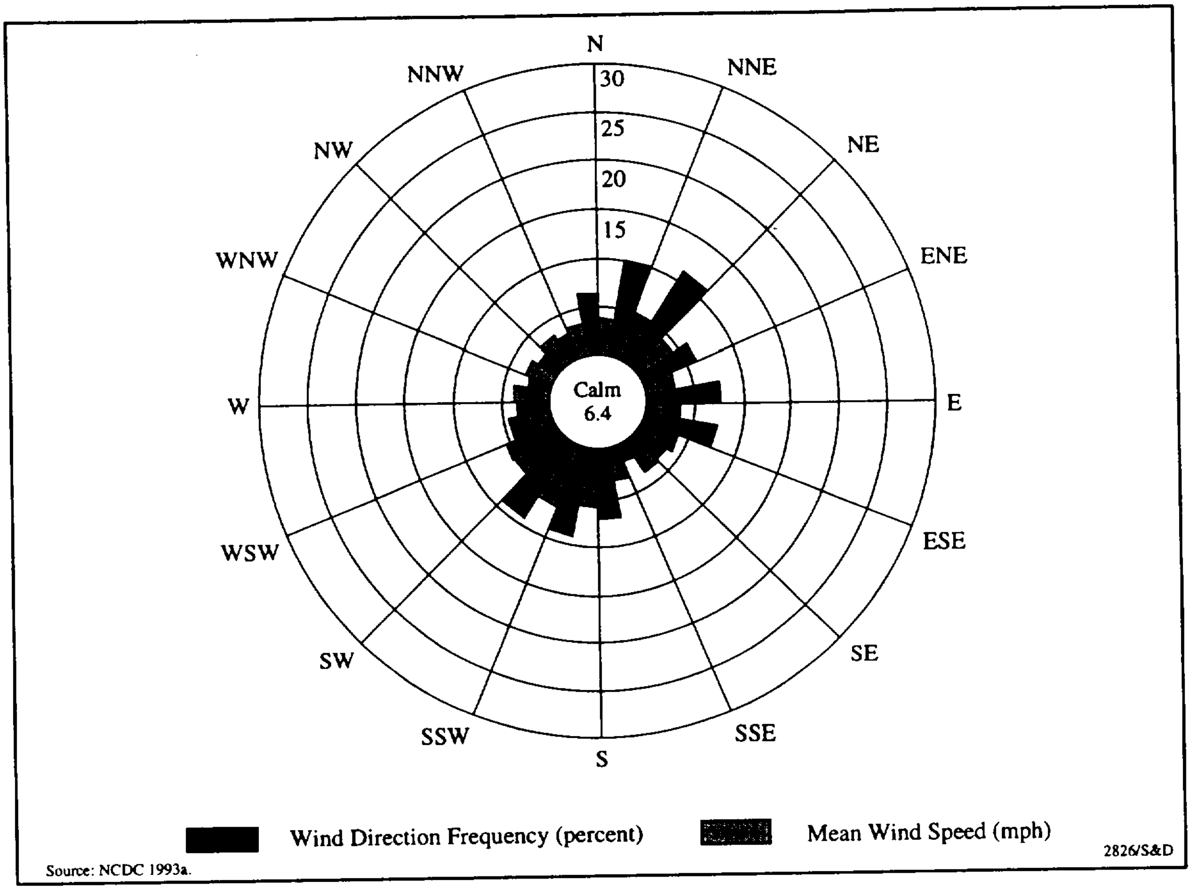


Figure F.1.2.3–1. Wind Distribution at Nevada Test Site, 1991 (10-meter level).

The average annual temperature at NTS is 19.5 °C (67.1 °F); temperatures vary from an average daily minimum of 0.9 °C (33.6 °F) in January to an average daily maximum of 41.1 °C (105.9 °F) in July. The average annual precipitation at NTS is 10.5 cm (4.13 in) (NOAA 1994d:3).

Annual precipitation in southern Nevada is very light and depends largely upon elevation. On NTS, the mesas receive an average annual precipitation of 23 cm (9 in), which includes winter snow accumulations. The lower elevations receive approximately 15 cm (6 in) of precipitation annually, with occasional snow accumulations lasting only a few days (NT DOE 1993e:2-17,2-19).

Precipitation usually falls in isolated showers with large variations in precipitation amounts within a shower area. Summer precipitation occurs mainly in July and August when intense heating of the ground below moist air masses triggers thunderstorm development. On rare occasions, a tropical storm will move northeastward from the coast of Mexico, bringing heavy precipitation during September and October.

Other than temperature extremes, severe weather in the region includes occasional thunderstorms, lightning, tornadoes, and sandstorms. Severe thunderstorms may produce high precipitation with durations of approximately 1 hour and may create a potential for flash flooding (NT DOE 1983a:26). Tornadoes have been observed in the region but are infrequent. The estimated probability of a tornado striking a point at NTS is 3.0×10^{-7}/yr (NRC 1986a:32).

Emission Rates. Table F.1.2.3–1 presents the emission rates for criteria and toxic/hazardous pollutants at NTS. These emission rates were used as input into the ISCST2 model to estimate pollutant concentrations.

Table F.1.2.3–1. Emission Rates of Criteria and Toxic/Hazardous Pollutants at Nevada Test Site[a]

Pollutant	Emission Rate (kg/yr)
Criteria Pollutants	
Carbon monoxide	b
Nitrogen dioxide	b
Particulate matter less than or equal to 10 microns in diameter[c]	86,820
Sulfur dioxide	71,125
Total suspended particulates[c]	86,820
Toxic/Hazardous Pollutants (no toxic sources indicated)	

[a] Based on permitted sources (1990-1992).
[b] No pollutant sources indicated.
[c] It is assumed that PM_{10} emissions are TSP emissions.
Note: yr=year.
Source: NV DCNR 1992a.

Modeling Assumptions. In order to estimate maximum pollutant concentrations at or beyond the NTS boundary for No Action, criteria pollutant emissions were modeled from actual stack locations using operating permit data on stack height, stack diameter, exit velocity, and exit temperature (NV DCNR 1992a).

Atmospheric Dispersion Characteristics. Data collected at the NTS meteorological monitoring station for 1991 indicate that unstable conditions occur approximately 26 percent of the time, neutral conditions approximately 37 percent, and stable conditions approximately 37 percent, on an annual basis.

F.1.2.4 Idaho National Engineering Laboratory

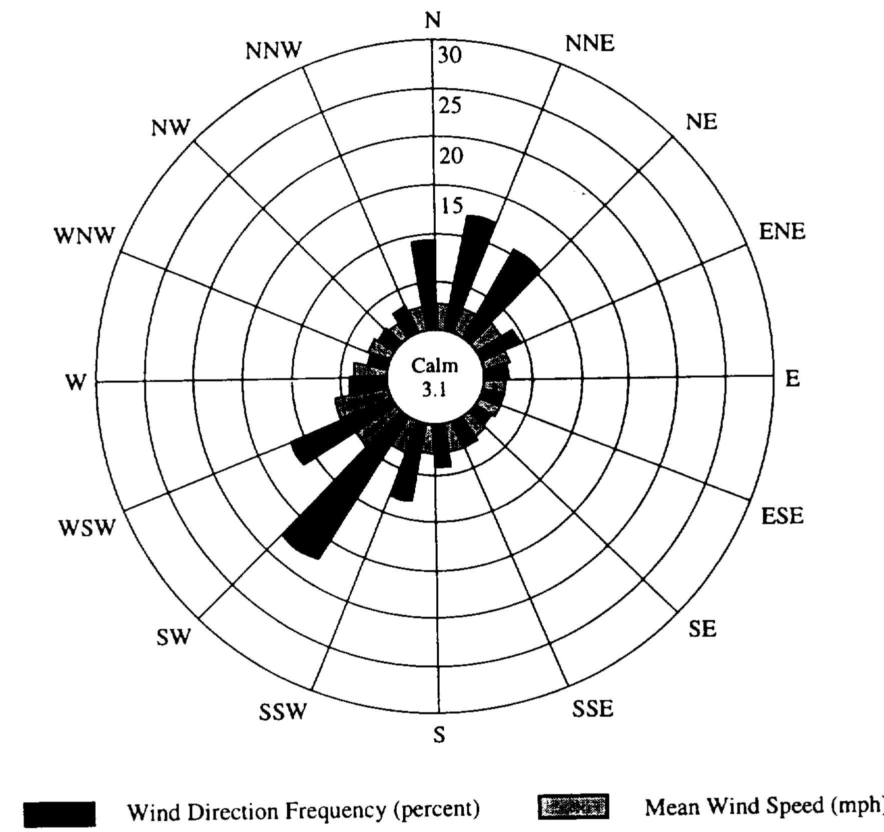
This section provides information on climatology and meteorology, modeling assumptions, atmospheric dispersion characteristics, and annual mean windspeeds and direction frequencies at INEL.

Climatology and Meteorology. Figure F.1.2.4–1 shows annual mean windspeeds and wind direction frequencies for 1992 measured at the 10-m (32.8-ft) level of the INEL meteorological tower. The wind rose shows that the maximum wind direction frequency is from the southwest with a secondary maximum from the north-northeast. The mean windspeed from the southwest is 5.2 m/s (11.6 mph) and from the north-northeast it is 2.8 m/s (6.3 mph); the maximum mean windspeed is 5.5 m/s (12.3 mph) from the west-southwest.

The historical wind data from the site indicate that prevailing wind directions are from the southwest to west-southwest with a secondary maximum from the north-northeast to northeast. The annual average windspeed is 3.4 m/s (7.5 mph) (IN DOE 1989b:28,30,55,77).

The average annual temperature at INEL is 5.6 °C (42.0 °F); average monthly temperatures vary from a minimum of -8.8 °C (16.1 °F) in January to a maximum of 20 °C (68 °F) in July. The average annual precipitation at INEL is 22.1 cm (8.71 in) (IN DOE 1989b:28,30,55,77).

The maximum instantaneous wind gust recorded at the Central Facilities Area Weather Station (6.1-m [20-ft] level) was 34.9 m/s (78 mph) from the west-southwest, and the maximum hourly average windspeed, also from the west-southwest, was 22.8 m/s (51 mph) (IN DOE 1989b:28,30,55,77).



Source: INEL 1993a:5.

Figure F.1.2.4–1. Wind Distribution at Idaho National Engineering Laboratory, 1992 (10-meter level).

Other than thunderstorms, severe weather is uncommon. The months of June, July, and August each average two to three thunderstorm days. Hail storms occur occasionally, with the hail usually smaller than 0.64-cm (0.25-in) diameter. Tornadoes are very infrequent in the area. Between 1950 and 1989, a total of five funnel clouds and no tornadoes were sighted within the boundary of INEL (IN DOE 1989b:100-102). The estimated probability of a tornado striking a point at INEL is 6.0×10^{-7} per year (NRC 1986a:32).

Emission Rates. Table F.1.2.4–1 presents the emission rates for criteria and toxic/hazardous pollutants at INEL. These emission rates were used as input into the ISCST2 model to estimate pollutant concentrations. INEL exceeds the applicable 227,000 kilograms (kg)/yr (250 short tons (tons)/yr) emissions criterion for carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matter less than or equal to 10 microns in diameter (PM_{10}), and is therefore classified as an existing major source for these pollutants. The classification of INEL as a major source may require further prevention of significant deterioration review than sites not classified as a major source.

Modeling Assumptions. In order to estimate maximum pollutant concentrations at or beyond the INEL site boundary, criteria pollutant emissions were modeled from actual stack locations using operating permit data on stack height, stack diameter, exit velocity, and exit temperature (INEL 1995a:1). Toxic/hazardous pollutant emissions were modeled from a centrally located stack at a height of 10 m (32.8 ft), with a stack diameter of 0.3 m (1 ft), an exit velocity of 0.03 m/s (0.1 ft/s), and an exit temperature equal to ambient temperature.

Table F.1.2.4–1. Emission Rates of Criteria and Toxic/Hazardous Pollutants at Idaho National Engineering Laboratory[a]

Pollutant	Emission Rate (kg/yr)
Criteria Pollutants	
CO	2,200,000
Lead	68
NO_2	3,000,000
PM_{10}[b]	900,000
SO_2	1,700,000
Total suspended particulates[b]	900,000
[Text deleted]	
Toxic/Hazardous Pollutants[c]	
1,3-Butadiene	390
[Text deleted]	
Acetaldehyde	180
Ammonia	6,500
Arsenic	24
Benzene	530
Carbon tetrachloride	28
[Text deleted.]	
Chromium-hexavalent	26
Cyclopentane	350
[Text deleted.]	
Formaldehyde	3,300
Hydrazine	8.3
[Text deleted]	
Hydrogen chloride	1,500
[Text deleted]	
Mercury	200
Methylene chloride	1,100
Naphthalene	16
Nickel	1,000
Nitric acid	97,000
Perchloroethylene	980
Phosphorous	210
Potassium hydroxide	2,100
Propionaldehyde	110
Styrene	4.7
Toluene	580
Trichloroethylene	4.5
Trimethylbenzene	87
Trivalent chromium	38

[a] Emissions from historical data (1990) are assumed for No Action (2005).
[b] It is assumed that PM_{10} emissions are TSP emissions.
[c] Hazardous/toxic air pollutants that are listed in State of Idaho regulations and are emitted in quantities that exceed screening criteria.
Source: DOE 1995v; INEL 1995a:1.

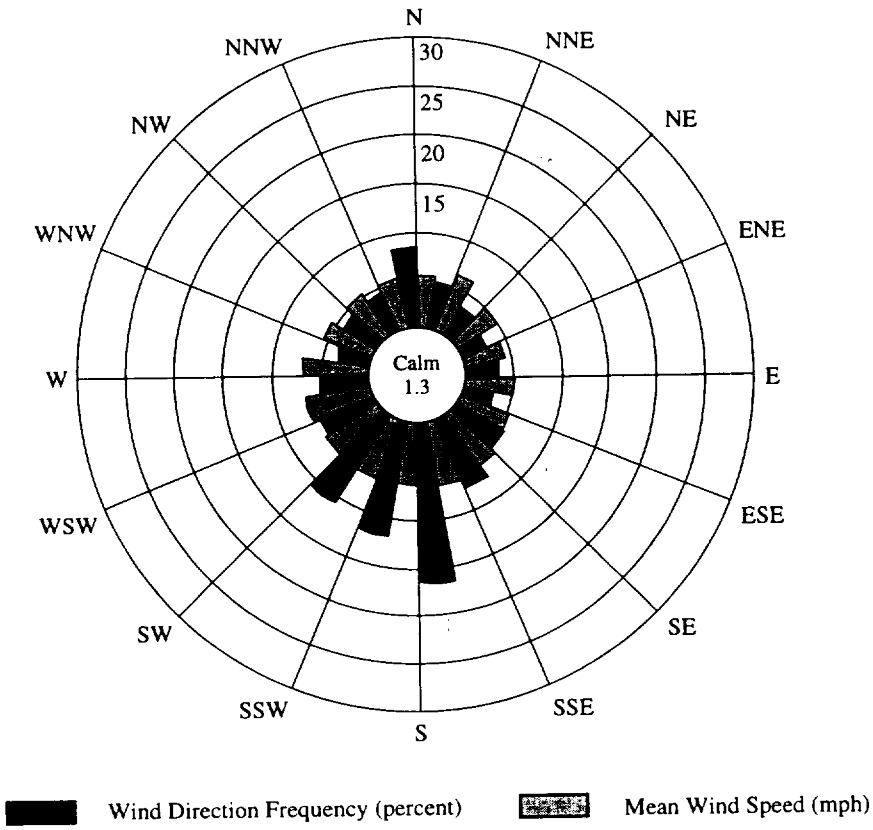


Figure F.1.2.5–1. Wind Distribution at Amarillo, 1991 (10-meter level).

Atmospheric Dispersion Characteristics. Data collected at INEL meteorological monitoring stations for 1992 indicate that unstable conditions occur approximately 22 percent of the time, neutral conditions approximately 26 percent, and stable conditions approximately 52 percent, on an annual basis.

F.1.2.5 Pantex Plant

This section provides information on climatology and meteorology, modeling assumptions, atmospheric dispersion characteristics, and annual mean windspeeds and direction frequencies at Pantex.

Climatology and Meteorology. Figure F.1.2.5–1 shows annual mean windspeeds and wind direction frequencies for 1991 measured at the 10-m (32.8-ft) level of the Amarillo National Weather Service station. The wind rose shows that the maximum wind direction frequency is from the south with a secondary maximum from the south-southwest. The mean windspeed from the south is 6.3 m/s (14.1 mph) and from the south-southwest it is 6.3 m/s (14.1 mph); the maximum mean windspeed is 6.6 m/s (14.8 mph) from the west.

Historical data indicate that prevailing wind directions are from the south to southwest. The annual average windspeed is 6.0 m/s (13.5 mph) (NOAA 1994c:3).

The average annual temperature at Pantex is 13.8 °C (56.9 °F); temperatures vary from an average daily minimum of -5.7 °C (21.8 °F) in January to an average daily maximum of 32.8 °C (91.1 °F) in July (NOAA 1994c:3).

The average annual precipitation at Pantex is 49.7 cm (19.6 in). Most of the annual precipitation falls between April and October and usually occurs from thunderstorm activity and the intrusion of warm, moist tropical air from the Gulf of Mexico. Snowfall has occurred in the area from October to April and averages nearly 42.9 cm (16.9 in) annually. The maximum 24-hour rainfall with a 100-year recurrence interval is approximately 16.5 cm (6.5 in). On average, the area can expect thunderstorms about 50 days/yr, hail 4 days/yr, and freezing rain 8 days/yr. During the 30-year period between 1954 and 1983, a total of 108 tornadoes were reported within a 1-degree latitude and longitude square area that includes Pantex. On average, fewer than four tornadoes occur in an area of 10,096 square kilometers (km^2) (3,898 square miles [mi^2]) surrounding Pantex per year. The estimated probability of a tornado striking a point at Pantex is $2.3x10^{-4}$/yr (NRC 1986a:32).

Emission Rates. Table F.1.2.5–1 presents the emission rates for criteria and toxic/hazardous pollutants at Pantex.

Table F.1.2.5–1. Emission Rates of Criteria and Toxic/Hazardous Pollutants at Pantex Plant

Pollutant	Emission Rate (kg/yr)
Criteria Pollutants	
CO	22,493
NO_2	54,056
Lead	185
PM_{10}	8,439
SO_2	0.1
Total suspended particulates	a
Hydrogen fluoride	1,176
Toxic/Hazardous Pollutants	
1,1,1-Chloroethane	22.74
[Text deleted]	
1,1,2-Trichloroethane	3.78
2-Nitropropane	1.71
[Text deleted]	
Alcohols	1,184
[Text deleted]	
Benzene	91.38
Carbon disulfide	27.05
Carbon tetrachloride	15.59
Chlorobenzene	1.79
Chromium	2.14
Cresol	0.05
Cresylic acid	0.05
[Text deleted]	
Dibenzofuran	0.07
[Text deleted]	
Ester glycol ethers	0.86
Ethyl benzene	1.51
Ethylene dichloride	1.33
Formaldehyde	57.89
Hydrogen chloride	1,106.11

Table F.1.2.5–1. Emission Rates of Criteria and Toxic/Hazardous Pollutants at Pantex Plant—Continued

Pollutant	Emission Rate (kg/yr)
Toxic/Hazardous Pollutants (continued)	
[Text deleted]	
Ketones	0.28
Mercury	0
Methanol	1,095.57
Methyl ethyl ketone	7,067.62
Methyl isobutyl ketone	0.62
Methylene chloride	182.07
Naphthalene	0.41
Nickel	0.16
Nitrobenzene	0.05
Phenol	2.23
[Text deleted]	
Tetrachloroethylene	6.44
Toluene	465.29
Trichloroethene	1.56
Trichloroethylene	19.50
Triethylamine	0
Xylene	222.15

[Text deleted.]

[a] Not available.
Source: PX DOE 1996b.

Modeling Assumptions. Baseline and No Action concentrations were based on actual source locations and stack parameters. In order to estimate maximum pollutant concentrations for alternatives at or beyond the Pantex boundary, criteria pollutant emissions and toxic/hazardous pollutant emissions were modeled from a centrally located stack in the Pantex complex at a height of 10 m (32.8 ft), with a stack diameter of 0.3 m (1.0 ft), an exit velocity of 0.03 m/s (0.1 ft/s), and an exit temperature equal to ambient temperature.

Atmospheric Dispersion Characteristics. Data collected at the Amarillo meteorological monitoring station for 1991 indicate that unstable conditions occur approximately 14 percent of the time, neutral conditions approximately 64 percent, and stable conditions approximately 22 percent, on an annual basis.

F.1.2.6 Oak Ridge Reservation

This section provides information on climatology and meteorology, modeling assumptions, atmospheric dispersion characteristics, and annual mean windspeeds and direction frequencies at ORR.

Meteorology and Climatology. The wind direction above the ridge tops and within the valley at ORR tends to follow the orientation of the valley. On an annual basis, the prevailing winds at the National Weather Service (NWS) station in the city of Oak Ridge are either up-valley, from west to southwest, or down-valley, from east to northeast. Figure F.1.2.6–1 shows mean windspeeds and direction frequencies for 1990 measured at the 30-m (100-ft) level of the ORR meteorology tower. The wind rose shows that the maximum wind direction frequency is from the east-northeast with a secondary maximum from the northeast. The mean windspeed from the east-northeast is 1.7 m/s (3.8 mph) and from the northeast it is 2.3 m/s (5.1 mph); the maximum mean windspeed is 3.3 m/s (7.4 mph) from the southwest.

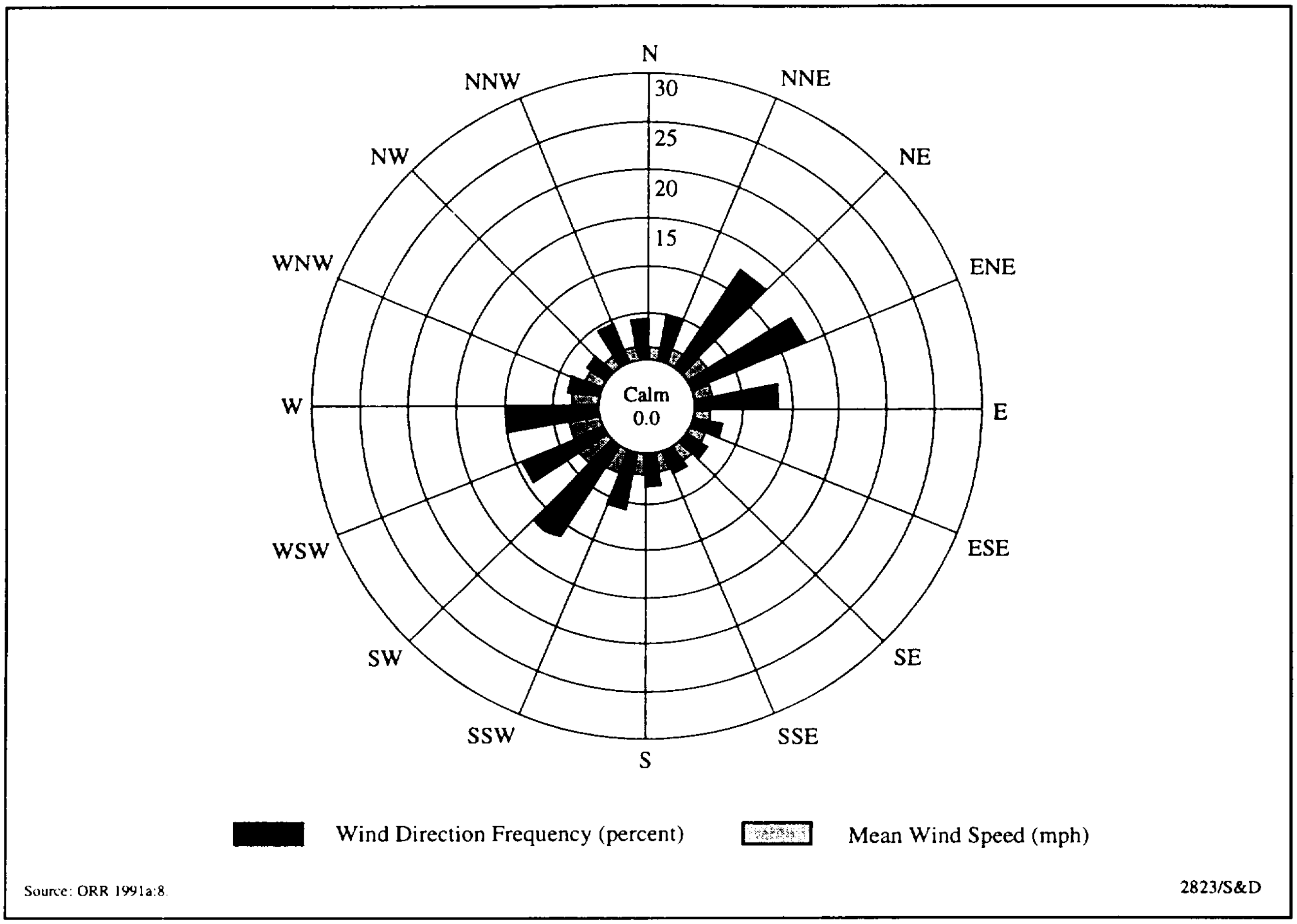


Figure F.1.2.6–1. Wind Distribution at Oak Ridge Reservation, 1990 (30-meter level).

The historical data indicate that prevailing wind directions are from the southwest and northeast quadrants. Mean annual windspeeds measured in the region are relatively low, averaging 2.0 m/s (4.4 mph) at the Oak Ridge NWS station at the 14-m (46-ft) level and 2.1 m/s (4.7 mph) at the 10-m (32.8-ft) level at the ORR Bethel Valley monitoring station (ORNL 1982a:2-95 – 2-113).

The average annual temperature at ORR is 13.7 °C (56.6 °F); temperatures vary from an average daily minimum of -3.8 °C (25.1 °F) in January to an average daily maximum of 30.4 °C (86.7 °F) in July. Relative humidity readings taken four times per day range from 51 percent in April to 92 percent in August and September (NOAA 1994c:3).

The average annual precipitation measured at ORR in Bethel Valley is 130.8 cm (51.5 in), while the average annual precipitation for the Oak Ridge NWS station is 136.6 cm (53.8 in). The maximum monthly precipitation recorded at the Oak Ridge NWS station was 48.95 cm (19.27 in) in July 1967, while the maximum rainfall in a 24-hour period was 19.0 cm (7.48 in) in August 1960. The average annual snowfall as measured at the Oak Ridge NWS station is 24.9 cm (9.8 in).

Damaging winds are uncommon in the region. Peak gusts recorded in the area range from 26.8 m/s (60 mph) to 30.8 m/s (69 mph) for the months of January through July; from 21.9 to 26.8 m/s (49 to 60 mph) for August, September, and December; and 16.1 to 20.1 m/s (36 to 45 mph) in October and November (ORNL 1982a:2-72). The fastest mile windspeed (the 1 mi [1.6 km] passage of wind with the highest speed for the day) recorded at the Oak Ridge NWS station for the period of 1958 through 1979 was 26.4 m/s (59 mph) in January 1959 (NOAA 1994c:3).

The extreme mile windspeed at a height of 9.1 m (30 ft) that is predicted to occur near ORR once in 100 years is approximately 39.8 m/s (89 mph). The approximate values for occurrence intervals of 10, 25, and 50 years are 28.6, 33.1, and 34.0 m/s (64, 74, and 76 mph), respectively (ORNL 1981a:3.3-7).

Between 1916 and 1972, 25 tornadoes were reported in the counties of Tennessee having borders within about 64 km (40 mi) of ORR (ORNL 1981a:3.3-7). The probability of a tornado striking a particular point in the vicinity of ORR is estimated to be 3.6×10^{-4} per year (ORNL 1982a:2-125).

On February 21, 1993, a tornado passed through the northeastern edge of ORR and caused considerable damage to a large number of structures in the nearby Union Valley Industrial Park. Damage to ORR from this tornado was relatively light. The windspeeds associated with this tornado ranged from 17.9 m/s (40 mph) to nearly 58 m/s (130 mph) (OR DOE 1993c:iii).

Emission Rates. Table F.1.2.6–1 presents the emission rates for criteria and toxic/hazardous pollutants at ORR. The emission rates were used as input into the ISCST2 model to estimate pollutant concentrations. ORR exceeds the applicable 227,000 kg/yr (250 tons/yr) emissions criterion for NO_2 and SO_2 and is therefore classified as an existing major source for these pollutants. The classification of ORR as a major source may require further prevention of significant deterioration review than sites not classified as a major source.

Table F.1.2.6–1. ***Emission Rates of Criteria and Toxic/Hazardous Pollutants at Oak Ridge Reservation***[a]

Pollutant	Emission Rate (kg/yr)
Criteria Pollutants	
CO	95,000
NO_2	870,000
PM_{10}	8,300
SO_2	972,000
Total suspended particulates	1,125,000
Toxic/Hazardous Pollutants	
1,1,1-Trichloroethane	220
Acetic acid	1
Chlorine	1,750
Hydrogen chloride	6,420
Hydrogen fluoride	70
Hydrogen sulfide	b
Methyl alcohol	26,400
Nitric acid	9,500
Sulfuric acid	2,500

[a] Emissions from historical data (1992) are assumed for No Action (2005).
[b] No sources of this pollutant have been identified.
Source: OR LMES 1996i.

Modeling Assumptions. In order to estimate maximum pollutant alternatives for concentrations at or beyond the ORR site boundary, criteria pollutant emissions and toxic/hazardous pollutant emissions were modeled from a centrally located stack in the Y–12 complex at a height of 10 m (32.8 ft), with a stack diameter of 0.3 m (1 ft), exit velocity of 0.03 m/s (0.1 ft/s), and exit temperature equal to ambient temperature.

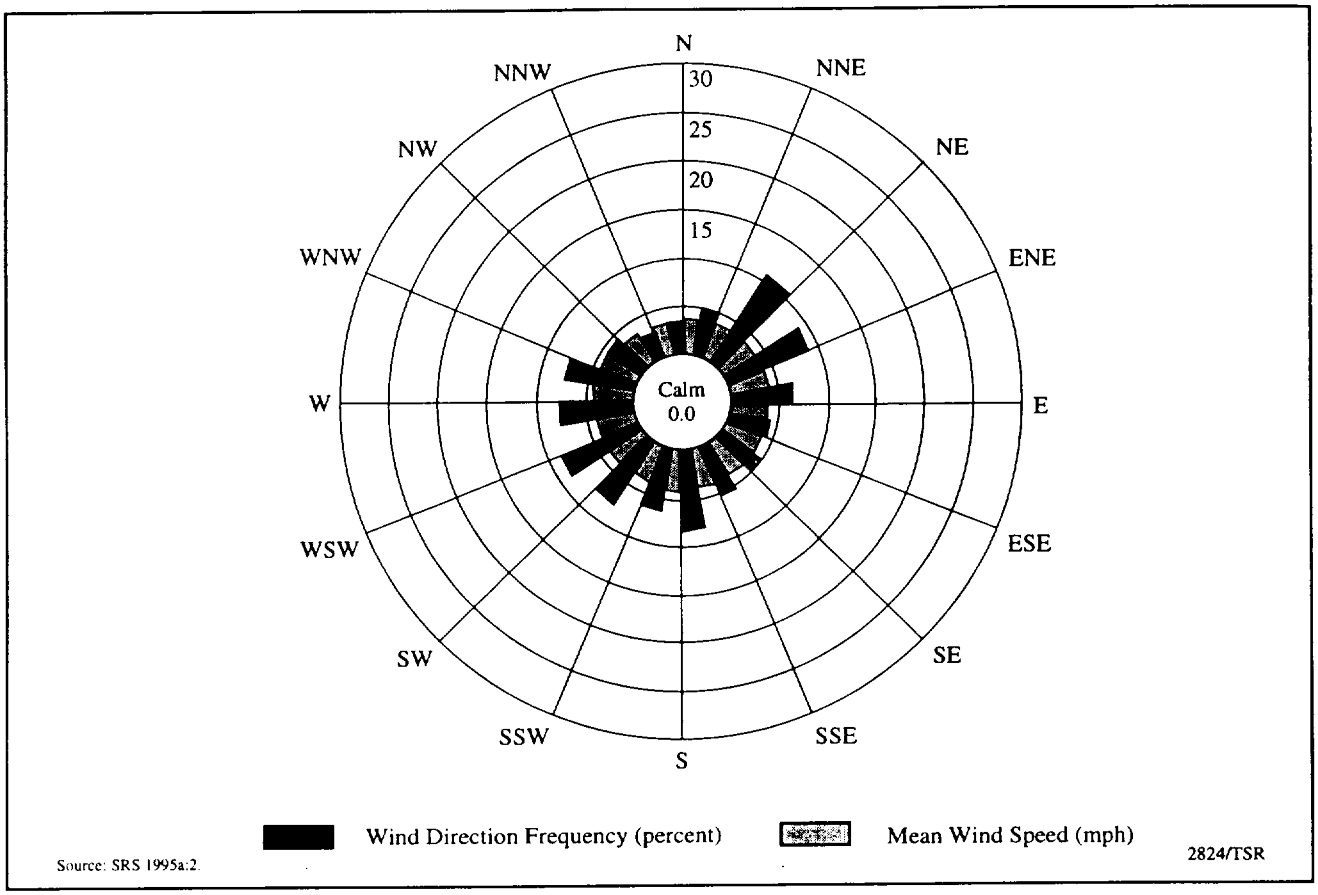


Figure F.1.2.7–1. Wind Distribution at Savannah River Site, 1991 (61-meter level).

Atmospheric Dispersion Characteristics. Data collected at the ORR meteorological monitoring station (Y–12 Plant east tower) for calendar year 1990 indicate that unstable conditions occur approximately 23 percent of the time, neutral conditions approximately 31 percent, and stable conditions approximately 46 percent, on an annual basis.

F.1.2.7 Savannah River Site

This section provides information on climatology and meteorology, modeling assumptions, atmospheric dispersion characteristics, and annual mean windspeeds and direction frequencies at SRS.

Climatology and Meteorology. Figure F.1.2.7–1 shows annual mean windspeeds and wind direction frequencies for 1991 measured at the 61-m (200-ft) level of the SRS H-Area Weather Station. The wind rose shows that the maximum wind direction frequency is from the northeast with a secondary maximum from the east-northeast. The mean windspeed from the northeast is 3.8 m/s (8.5 mph) and from the east-northeast it is 3.8 m/s (8.5 mph); the maximum mean windspeed is 4.1 m/s (9.2 mph) from the west-northwest.

The historical wind data from the site indicate that there is no predominant wind direction at SRS. The highest directional frequency is from the northeast. The average annual windspeed is 3.75 m/s (8.4 mph).

The average annual temperature at SRS is 17.3 °C (63.2 °F); temperatures vary from an average daily minimum of 0 °C (32 °F) in January to an average daily maximum of 33.2 °C (91.7 °F) in July. Relative humidity readings taken four times per day range from 45 percent in April to 92 percent in August and September.

The average annual precipitation at SRS is 113.4 cm (44.7 in). Precipitation is distributed fairly evenly throughout the year, with the highest precipitation in summer, 32.7 cm (12.87 in), and the lowest in autumn, 21.2 cm (8.34 in). Although snow can fall from November through April, the average annual snowfall is only 2.8 cm (1.1 in); large snowfalls are rare.

Winter storms in the SRS area occasionally bring strong, gusty surface winds with speeds as high as 22.8 m/s (51 mph). Thunderstorms can generate winds with speeds as high as 21.5 m/s (48.1 mph) and even stronger gusts. The fastest 1-minute windspeed recorded at Augusta between 1952 and 1993 was 27.7 m/s (62 mph) (NOAA 1994c:3).

The average number of thunderstorm days per year at SRS is 56. From 1954 to 1983, 37 tornadoes were reported in a 1-degree square of latitude and longitude that includes SRS. This frequency of occurrence amounts to an average of about one tornado per year. The estimated probability of a tornado striking a point at SRS is 7.1×10^{-5} per year (NRC 1986a:32). Since operations began at SRS in 1953, nine tornadoes have been confirmed on or near SRS. Nothing more than light damage was reported in any of these storms, with the exception of a tornado near SRS. Nothing more than light damage was reported in any of these storms, with the exception of a tornado in October 1989. That tornado caused considerable damage to timber resources in an undeveloped wooded area of SRS (WSRC 1990b:1).

From 1899 to 1980, 13 hurricanes occurred in Georgia and South Carolina, for an average frequency of about 1 hurricane every 6 years. Three hurricanes were classified as major. Because SRS is about 160 km (99.4 mi) inland, the winds associated with hurricanes have usually diminished below hurricane force (below a sustained speed of 33.5 m/s [75.0 mph]) before reaching the site (DOE 1992e:4-115).

Emissions Rates. Table F.1.2.7–1 presents the emission rates for criteria and toxic/hazardous pollutants at SRS. SRS exceeds the applicable 227,000 kg/yr (250 tons/yr) emissions criterion for CO, NO_2, SO_2 and PM_{10} and is therefore classified as an existing major source for these pollutants. The classification of SRS as a major source may require further prevention of significant deterioration review than sites not classified as a major source.

Modeling Assumptions. Emission rates for baseline and No Action for criteria and toxic/hazardous pollutants were based upon the latest sitewide emissions inventory data for the year 1990. Baseline and No Action concentrations were based on actual source locations and stack parameters. In order to estimate maximum criteria and toxic/hazardous pollutant concentrations at or beyond the SRS site boundary for the various storage and disposition alternatives, criteria pollutant emissions and toxic/hazardous pollutant emissions were modeled from a centrally located stack at a height of 10 m (32.8 ft), with a stack diameter of 0.3 m (1 ft), exit velocity of 0.03 m/s (0.1 ft/s), and exit temperature equal to ambient temperature.

Atmospheric Dispersion Characteristics. Data collected at SRS meteorological monitoring station for 1991 indicate that unstable conditions occur approximately 38 percent of the time, neutral conditions approximately 43 percent, and stable conditions approximately 19 percent, on an annual basis (SRS 1995a:2).

F.1.2.8 Rocky Flats Environmental Technology Site

This section provides information on climatology and meteorology, modeling assumptions, atmospheric dispersion characteristics, and annual mean windspeeds and direction frequencies at RFETS.

Climatology and Meteorology. Figure F.1.2.8–1 shows annual mean windspeeds and wind direction frequencies for 1990 measured at the 61.0-m (200-ft) level of the 61-m (200-ft) tower in the west buffer zone. The wind rose shows that the maximum wind direction frequency is west-northwest with a secondary maximum from the west. The mean windspeed from the west-northwest is 6.3 m/s (14.1 mph); the maximum mean windspeed is 5.7 m/s (12.8 mph) from the west.

Table F.1.2.7–1. Emission Rates of Criteria and Toxic/Hazardous Pollutants at Savannah River Site[a]

Pollutant	Emission Rate (kg/yr)	
Criteria Pollutants		
CO	404,449	
NO_2	4,278,380	
PM_{10}	1,963,180	
SO	9,454,199	
Total suspended particulates	4,430,890	
Hydrogen fluoride	16,690	
Toxic/Hazardous Pollutants	**Point & Volume Source (kg/yr)**	**Area Source[b] (kg/yr/m²)**
3,3-Dichlorobenzidine	211.0	[c]
Acrolein	[c]	1.94×10^{-3}
Benzene	129,772.3	0.21
Bis (chloromethyl) ether	211.0	[c]
Cadmium oxide	243.0	[c]
Chlorine	21,146.7	10.11
Chloroform	1,035,006	13.6
Cobalt	5,970.2	4.58×10^{-4}
Formic acid	46,949.5	[c]
Manganese	27,882.1	2.61
Mercury	917.5	1.15×10^{-3}
Nickel	23,022.5	6.02
Nitric acid	1,150,525.8	[c]
Parathion	[d]	[d]
Phosphoric acid	14,859.8	[c]

[a] Emissions from historical data (1990) are assumed for No Action (2005).
[b] Some toxic/hazardous pollutant sources were modeled as area sources, the remainder were modeled as point or volume sources.
[c] No sources of this pollutant have been identified.
[d] Data not available.
Source: SRS 1995a:10; WSRC 1993c.

The historical data indicate that the predominant wind direction is from the west-northwest. The average annual windspeed is 3.8 m/s (8.6 mph) (NOAA 1994a:3).

The average annual temperature at RFETS is 10.2 °C (50.3 °F); temperatures vary from an average daily minimum of -8.8 °C (16.1 °F) in January to an average daily maximum of 31.2 °C (88.2 °F) in July. The average annual precipitation at RFETS is 39.1 cm (15.4 in) (NOAA 1994a:3).

Winter storms in the RFETS area can generate winds with speeds as high as 21.5 m/s (48 mph) and even stronger gusts. The fastest 1-minute windspeed recorded in Denver, Colorado, was 20.6 m/s (46 mph) (NOAA 1994a:3).

The average number of thunderstorm days per year at RFETS is 42. From 1954 to 1983, 13 tornadoes were reported for a 1-degree square of latitude and longitude that includes RFETS. This frequency of occurrence amounts to an average of less than one tornado per year. The estimated probability of a tornado striking a point at RFETS is 2.0×10^{-5} per year (NRC 1986a:32).

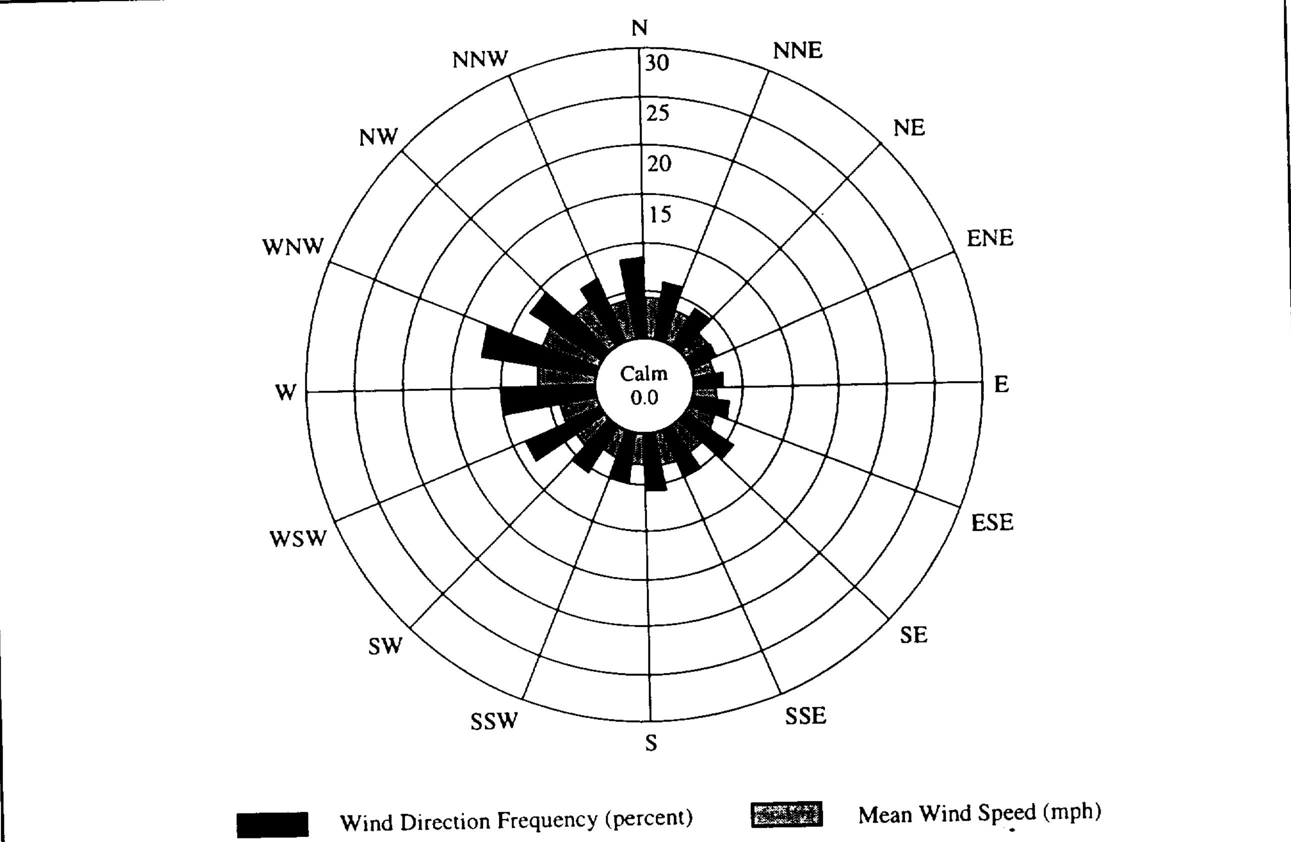


Figure F.1.2.8–1. ***Wind Distribution at Rocky Flats Environmental Technology Site, 1990 (61-meter level).***

Emission Rates. Table F.1.2.8–1 presents the emission rates for criteria and toxic/hazardous pollutants at RFETS. These emission rates were used as input into the ISCST2 model to estimate pollutant concentrations.

Modeling Assumptions. In order to estimate maximum pollutant concentrations at or beyond the RFETS site boundary, criteria pollutant emissions and toxic/hazardous pollutant emissions were modeled from a centrally located stack in RFETS at a height of 10 m (32.8 ft), with a stack diameter of 0.3 m (1 ft), an exit velocity of 0.03 m/s (0.1 ft/s), and an exit temperature equal to ambient temperature.

Atmospheric Dispersion Characteristics. Data collected at RFETS meteorological monitoring station for 1990 indicate that unstable conditions occur approximately 59 percent of the time, neutral conditions approximately 26 percent, and stable conditions approximately 15 percent, on an annual basis.

F.1.2.9 Los Alamos National Laboratory

This section provides information on climatology and meteorology, modeling assumptions, atmospheric dispersion characteristics, and annual mean windspeed and direction frequencies at LANL.

Climatology and Meteorology. Figure F.1.2.9–1 shows annual mean windspeed and wind direction frequencies for 1991 measured at the 11.5-m (37-ft) level of the Technical Area (TA)-6 meteorological tower. The wind

Table F.1.2.8–1. Emission Rates of Criteria and Toxic/Hazardous Pollutants at Rocky Flats Environmental Technology Site[a]

Pollutant	Emission Rate (kg/yr)
Criteria Pollutants	
CO	39,200
NO_2	183,000
PM_{10}	10,400
SO_2	13,100
State Mandated Pollutants	
Hydrogen sulfide	0.467
Total suspended particulates	12,600
Toxic/Hazardous Pollutants[b]	
1,1,2-Trichloro-1,2,2-trifluoroethane	109
Carbon tetrachloride	53.5
Methylene chloride	53.3
Trichloroethane	136

[a] Emissions from historical data (permits 1991-1994) are assumed for No Action (2005).
[b] Only those emitted at rates greater than 45 kg/yr are listed.
Source: RFETS 1995a:1.

rose shows that the maximum wind direction frequency is from the west-northwest with a secondary maximum from the west. The mean windspeed from the west-northwest is 3.2 m/s (7.2 mph), which is also the maximum mean windspeed. The mean windspeed is 3 m/s (6.7 mph) from the west.

The historical wind data from the site indicate that the prevailing wind directions are from the south through northwest. The average annual windspeed measured is 2.8 m/s (6.3 mph) (LANL 1995s:II-11).

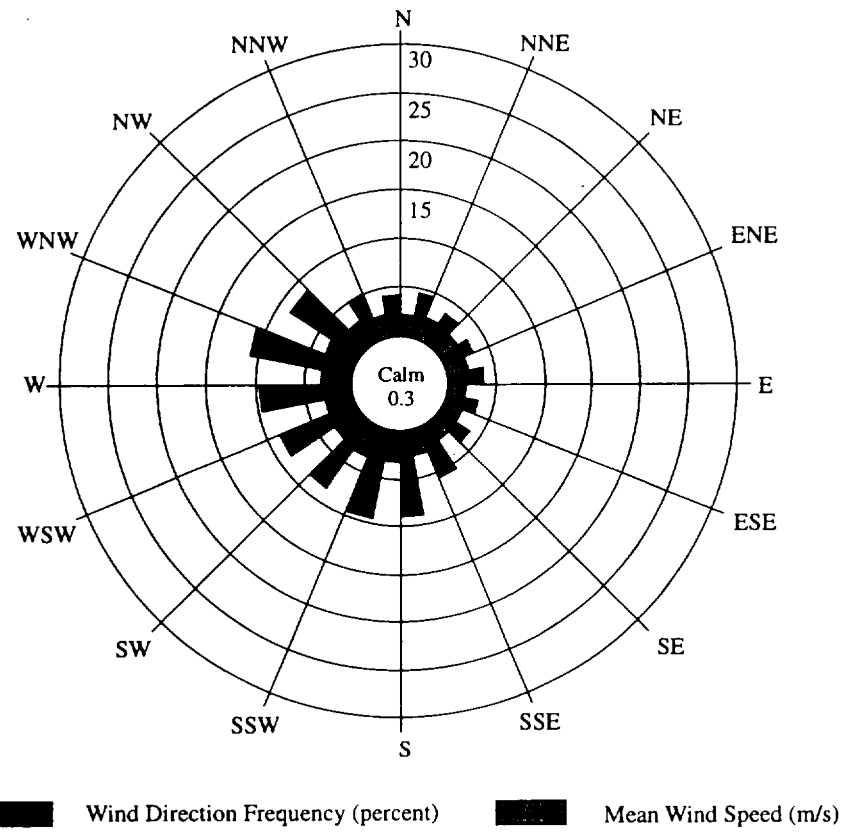
The average annual temperature at LANL is 8.8 °C (47.8 °F). In July, the average daily high temperature is 27.2 °C (81 °F), and the average nighttime low temperature is 12.8 °C (55 °F). The highest recorded temperature is 35 °C (95 °F). The average daily January high is 4.4 °C (40 °F), and the average nighttime low is -8.3 °C (17 °F). The lowest recorded temperature is -27.8 °C (-18 °F). Monthly average values of the dew point temperature range from -9.4 °C (15.0 °F) in January to 8.9 °C (48 °F) in August, when moist subtropical air invades the region. Fog is rare in Los Alamos, occurring on fewer than 5 days per year (LANL 1995s:II-8,II-11).

The average annual precipitation at LANL is 47.6 cm (18.7 in). Most of the annual precipitation falls during the months of July and August and usually occurs from convective storms. Snowfall averages nearly 150 cm (59 in). The maximum 24-hour rainfall is approximately 8.8 cm (3.5 in) (LANL 1994a:II-11).

The average number of thunderstorm days per year is 58, with most occurring during the summer. The estimated probability of a tornado striking a point at LANL is 2×10^{-5} per year (NRC 1986a:32). Historically, no tornadoes have been reported to have touched down in Los Alamos County (LANL 1993b:II-9).

Emission Rates. Table F.1.2.9–1 presents the emission rates for criteria and toxic/hazardous pollutants at LANL. These emission rates were used as input into the ISCST2 model, to estimate pollutant concentrations.

Modeling Assumptions. Additional model input used to estimate maximum pollutant concentrations at or beyond the LANL site boundary include the following: criteria pollutant emissions were modeled from actual



Source: LANL 1992a:6.

Figure F.1.2.9–1. Wind Distribution at Los Alamos National Laboratory, 1991 (11.5-meter level).

stack locations using actual stack heights, stack diameter, exit velocity, and exit temperature, taken from operating permits; toxic/hazardous pollutant emissions were modeled from a centrally located stack in the LANL facility at a height of 10 m (32.8 ft), stack diameter of 0.3 m (1 ft), exit velocity of 0.03 m/s (0.1 ft/s), and exit temperature equal to ambient temperature.

Atmospheric Dispersion Characteristics. Data collected at the TA-6 meteorological tower for 1991 indicate that unstable conditions occur approximately 45 percent of the time, neutral conditions approximately 21 percent of the time, and stable conditions approximately 34 percent of the time, on an annual basis.

Table F.1.2.9–1. Emission Rates of Criteria and Toxic/Hazardous Pollutants at Los Alamos National Laboratory[a]

Pollutant	Emission Rate (kg/yr)
Criteria Pollutant	
CO	21,583
Lead	26
NO_2	55,314
PM_{10}	2,983
SO_2	704.6
Total suspended particulates[b]	2,983
Hazardous and Other Toxic Compounds	
1, 1, 2-Trichloroethane	927
2-Butoxyethanol	123
Acetic acid	537
Ammonia	799
Chloroform	533
Ethyl acetate	89
Ethylene glycol	72
Formaldehyde	49
Heptane (n-heptane)	1,849
Hexane (n-hexane)	77
Hydrogen chloride	638
Hydrogen fluoride (as F)	242
Isopropyl alcohol	539
Kerosene	260
Methyl alcohol	589
Methyl ethyl ketone	1,864
Methylene chloride	1,104
Nickel	55
Nitric acid	661
Nitrogen oxide	428
Propane sultone	205
Stoddard solvent	264
Toluene	2,483
Trichloroethylene	210
Tungsten (as W) (insoluble)	109
VM&P naptha	613
Xylene (o-, m-, p-isomers)	1,762

[a] Emissions from historical data (1990) are assumed for No Action (2005).

[b] It is assumed that PM_{10} emissions are total suspended particulates emissions.

Source: LANL 1994a.

F.1.3 Air Pollutant Emissions

Potential ambient air quality impacts of the emissions due to operation of the various storage and disposition facilities at each site were analyzed using ISCST2 as described in Section F.1.1. The source of the facility emissions is assumed to be that which is described under the Modeling Assumptions subsection in each of the preceding descriptions of the sites. The model input data include the emission inventories for each of the facilities as presented in Tables F.1.3–1 through F.1.3–14.

Table F.1.3–1. Emission Rates of Pollutants for Upgrade of Existing Facilities

Pollutant	Hanford[b] (kg/yr)	INEL: Without RFETS or LANL Material (kg/yr)	INEL: With RFETS and LANL Material (kg/yr)	Pantex: With RFETS Pits (kg/yr)	Pantex: Without RFETS or LANL Material (kg/yr)	Pantex: With RFETS and LANL Material (kg/yr)	ORR (kg/yr)	SRS[a]: With RFETS Non-pit Material (kg/yr)	SRS[a]: With RFETS and LANL Material (kg/yr)
Criteria Pollutants									
CO	51.7	900	920	0	0	3,700	c	91	122
NO_2[d]	200	3,000	3,000	0	0	4,600	c	2,951	4,037
PM_{10}[e]	4.54	1,000	1,100	0	0	1,200	c	227	308
SO_2	3.36	4,900	5,200	0	0	85	c	8,626	11,884
Total suspended particulates[e]	4.54	1,000	1,100	0	0	1,200	c	227	308
Volatile organic compounds	50.8	84	86	0	0	550	c	23	32
Toxic/Hazardous Pollutants				0	0				
Ammonia	0	0	0	0	0	0	0	0	0
Chlorine	0	<1	<1	0	0	5	c	0	0
Hydrazine	0	<1	<1	0	0	<1	c	0	0
Hydrogen chloride	0	1	1	0	0	0	11.3	0	0
Hydrogen fluoride	0	1	1	0	0	0	11.3	0	0
Nitric acid	0	0	0	0	0	6	113.4	0	0
Phosphoric acid	0	<1	<1	0	0	<1	c	0	0
Sulfuric acid	0	<1	<1	0	0	<1	c	0	0

[a] Applies only to the incremental emissions associated with the upgrade subalternatives (RFETS non-pit subalternative and RFETS and LANL subalternative). The emissions associated with the storage of SRS plutonium in the Actinide Storage and Packaging Facility are included in the No Action emissions.

[b] Applies to both with and without RFETS and LANL Pu material.

[c] No sources of this pollutant have been identified.

[d] For some upgrades, the associated data report states the emission is NO_x. In these instances, NO_x is conservatively assumed to be NO_2.

[e] It is assumed that PM_{10} emissions are total suspended particulate emissions.

Source: DOE 1996e; FDI 1996a:1; HF DOE 1995e:1; HF DOE 1996a; IN DOE 1996a; OR MMES 1996a; PX MH 1994a; SR DOE 1994e; SRS 1996a:4.

Table F.1.3–2. Emission Rates of Pollutants for the Consolidated Plutonium Storage Facility

		NTS			Pantex		
Pollutant	**Hanford (kg/yr)**	**New Facility and Modify P-Tunnel (kg/yr)**	**New Facility (kg/yr)**	**INEL (kg/yr)**	**New Facility and Modify Zone 12 South (kg/yr)**	**New Facility (kg/yr)**	**SRS (kg/yr)**
Criteria Pollutants							
CO	520	2,500	2,300	3,400	3,700	3,300	1,600
NO_2	2,000	3,600	3,400	97,000	4,600	4,300	38,000
PM_{10}[a]	50	780	700	6,900	1,200	1,100	2,600
SO_2	34	70	62	160,000	85	79	61,000
Total suspended particulates[a]	50	780	700	6,900	1,200	1,100	2,600
Volatile organic compounds	58	370	330	400	550	500	190
Toxic/Hazardous Pollutants							
Chlorine	5	8	5	3	5	4	8
Hydrazine	<1	<1	<1	<1	<1	<1	<1
Nitric acid	6	5	6	6	6	6	6
Phosphoric acid	<1	<1	<1	<1	<1	<1	<1
Sulfuric acid	<1	<1	<1	<1	<1	<1	<1

[a] It is assumed that PM_{10} emissions are TSP emissions.
Source: DOE 1996e; NT DOE 1996a; PX DOE 1996a.

Table F.1.3–3. Emission Rates of Pollutants for the Collocated Plutonium and Highly Enriched Uranium Storage Facilities

		NTS				ORR			
Pollutant	**Hanford (kg/yr)**	**New Facility and Modify P-Tunnel (kg/yr)**	**New Facility (kg/yr)**	**INEL (kg/yr)**	**Pantex (kg/yr)**	**New Pu Storage Facility Only (kg/yr)**	**New Pu Storage Facility and Upgrade Y–12 (kg/yr)**	**New Pu and HEU Facilities (kg/yr)**	**SRS (kg/yr)**
Criteria Pollutants									
CO	520	2,800	2,500	4,000	3,800	1,900	1,900	2,100	1,700
NO_2	2,000	3,800	3,600	120,000	4,600	48,000	48,000	55,000	42,000
PM_{10} [a]	50	890	780	8,200	1,300	3,300	3,450	3,800	2,900
SO_2	34	70	66	200,000	86	79,000	79,000	90,000	69,000
Total suspended particulates[a]	50	890	780	8,200	1,300	3,300	3,300	3,800	2,900
Volatile organic compounds	58	420	370	470	570	220	220	250	200
Toxic/Hazardous Pollutants									
Chlorine	6	8	6	4	5	6	6	8	10
Nitric acid	95	5	95	95	95	6	119	95	95
Hydrazine	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hydrogen chloride	9.0	9.0	9.0	9.0	9.0	b	11.3	9.0	9.0
Hydrogen fluoride	9.0	9.0	9.0	9.0	9.0	b	11.3	9.0	9.0
Phosphoric acid	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sulfuric acid	<1	<1	<1	<1	<1	<1	<1	<1	<1

[a] It is assumed that PM_{10} emissions are total suspended particulates emissions.

[b] No sources of this pollutant have been identified.

Source: DOE 1996e; DOE 1996f; NT DOE 1996a; OR MMES 1996a.

Table F.1.3–4. Emission Rates of Pollutants for the Pit Disassembly/Conversion Facility

Pollutant	Hanford (kg/yr)	NTS (kg/yr)	INEL (kg/yr)	Pantex (kg/yr)	ORR (kg/yr)	SRS (kg/yr)
Criteria Pollutants						
CO	a	a	a	a	a	a
NO_2	a	a	a	a	a	a
PM_{10}	a	a	a	a	a	a
SO_2	a	a	a	a	a	a
Total suspended particulates	a	a	a	a	a	a
Volatile organic compounds	1,500	1,500	1,500	1,500	1,500	1,500
Toxic/Hazardous Pollutants						
Cleaning solvents	750	750	750	750	750	750

[a] No sources of this pollutant have been identified. The pit disassembly/conversion process involves pure Pu materials that would not require chemical processing. The emissions estimates for the facility are based on data from similar processes at LANL's TA-55 facility. The ventilation system for the pit disassembly/conversion facility would be used specifically for contamination control and would use a large volume of air to assure contamination control. Primary confinement would be provided by a glove box system and associated zone air-handling system. There would be four stages of HEPA filters on the glovebox exhaust that would eliminate (or reduce below detection limits) a minimum of 99.95 percent of nonradioactive particulates. Radioactive particulate emissions are discussed in Section 4.3.1.9. The glovebox exhaust would be mixed with room air exhaust, which also has two stages of HEPA filters. The use of HEPA filters would not reduce VOC emissions because VOCs are not in a particulate form. There would also be process-specific scrubbers, vacuum traps, and filters that reduce the chance of criteria or toxic/hazardous pollutants releases from occurring. Because of the processing technology (which does not create some of the criteria pollutants), the defense-in-depth for Pu processing systems, and the extensive HEPA filtration (which removes the remaining criteria pollutants), emissions for criteria pollutants other than VOCs are expected to be below detection limits.

Source: LANL 1996d.

Table F.1.3–5. Emission Rates of Pollutants for the Plutonium Conversion Facility

Pollutant	Hanford (kg/yr)	NTS (kg/yr)	INEL (kg/yr)	Pantex (kg/yr)	ORR (kg/yr)	SRS (kg/yr)
Criteria Pollutants						
CO	4,000	4,000	4,000	4,000	4,000	4,000
NO_2[a]	4,500	4,500	4,500	4,500	4,500	4,500
PM_{10}[b]	12	12	12	12	12	12
SO_2	10	10	10	10	10	10
Total suspended particulates[b]	12	12	12	12	12	12
Toxic/Hazardous Pollutants						
Ammonia	10	10	10	10	10	10
Chlorine	7.5	7.5	7.5	7.5	7.5	7.5
Ethanol	20	20	20	20	20	20
Hydrogen chloride	12	12	12	12	12	12
Hydrogen fluoride	0.8	0.8	0.8	0.8	0.8	0.8
Hydrazine	<1	<1	<1	<1	<1	<1
Toxic/Hazardous Pollutants (continued)						
Nitric Acid	3	3	3	3	3	3
Phosphoric acid	<1	<1	<1	<1	<1	<1
Sulfuric acid	<1	<1	<1	<1	<1	<1
Trichloroethylene	450	450	450	450	450	450
Cleaning solvents	100	100	100	100	100	100

[a] The data report states the emission is NO_x but has been conservatively assumed to be NO_2.

[b] It is assumed that PM_{10} emissions are TSP emissions.

Source: LANL 1996c.

Table F.1.3–6. Emission Rates of Pollutants for the Generic Mixed Oxide Fuel Fabrication Facility

Pollutant	Hanford (kg/yr)	NTS (kg/yr)	INEL (kg/yr)	Pantex (kg/yr)	ORR (kg/yr)	SRS (kg/yr)	Generic (kg/yr)
Criteria Pollutants							
CO	[a]	[a]	[a]	[a]	[a]	[a]	[a]
NO_2	[a]	[a]	[a]	[a]	[a]	[a]	[a]
PM_{10}	[a]	[a]	[a]	[a]	[a]	[a]	[a]
SO_2	[a]	[a]	[a]	[a]	[a]	[a]	[a]
Total suspended particulates	[a]	[a]	[a]	[a]	[a]	[a]	[a]
Volatile organic compounds	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Toxic/Hazardous Pollutants							
Cleaning solvents	<2,500	<2,500	<2,500	<2,500	<2,500	<2,500	<2,500

[a] No sources of this pollutant have been identified. The MOX fuel fabrication process involves pure Pu materials that would require minimal chemical processing. The emissions estimates for the facility are based on operational experience at European MOX facilities, the glovebox ventilation system design, and the actual process. Feed material preparation and fabrication of fuel pellets would be done in gloveboxes to control contamination for normal operations. The ventilation system for the MOX fuel fabrication facility would be used specifically for contamination control and would use a large volume of air to assure contamination control. There would be essentially four stages of HEPA filters on the glovebox exhaust that would eliminate (or reduce below detection limits) a minimum of 99.95 percent of nonradioactive particulates. Radioactive particulate emissions are discussed in Section 4.3.5.1.9. The glovebox exhaust would be mixed with room air exhaust, which also has two stages of HEPA filters for further filtration before release to the environment. The use of HEPA filters would not reduce VOC emissions because VOCs are not in a particulate form. There would be process-specific scrubbers, vacuum traps, and filters that reduce the chance of criteria or toxic/hazardous pollutant releases from occurring. Because of the processing technology (which does not create some of the criteria pollutants), the defense-in-depth for Pu processing systems, and the extensive HEPA filtration (which removes the remaining criteria pollutants), emissions for criteria pollutants other than VOCs are expected to be below detection limits.

Source: LANL 1996b.

Table F.1.3–7. Emission Rates of Pollutants for the Direct Disposition Alternative—Deep Borehole Complex

Pollutant	Generic[a] (kg/yr)
Criteria Pollutants	
CO	11,263
NO_2[b]	30,898
PM_{10}[c]	11,812
SO_2	2,822
Total suspended particulates[c]	11,812
Toxic/Hazardous Pollutants	
Hydrocarbons	2,831

[a] Includes the surface processing and the drilling and emplacing-borehole sealing facilities.

[b] The data report states the emission is NO_x but has been conservatively assumed to be NO_2.

[c] It is assumed that PM_{10} emissions are total suspended particulate emissions.

Source: LLNL 1996a.

Table F.1.3–8. Emission Rates of Pollutants for the Immobilization Disposition Alternative—Ceramic Immobilization Facility and Deep Borehole Complex

Pollutant	Hanford (kg/yr)	NTS (kg/yr)	INEL (kg/yr)	Pantex (kg/yr)	ORR (kg/yr)	SRS (kg/yr)	Generic Borehole (kg/yr)
Criteria Pollutants							
CO	32,000	32,000	32,000	32,000	32,000	32,000	11,235
NO_2[a]	9,000	9,000	9,000	9,000	9,000	9,000	31,344
PM_{10}[b]	400	400	400	400	400	400	11,340
SO_2	500	500	500	500	500	500	2,799
Total suspended particulates[b]	400	400	400	400	400	400	11,340
Volatile organic compounds	95	95	95	95	95	95	trace
Toxic/Hazardous Pollutants							
Hydrocarbons	950	950	950	950	950	950	2,806

[a] The data report states the emission is NO_x but has been conservatively assumed to be NO_2.

[b] It is assumed that PM_{10} emissions are TSP emissions.

Source: LLNL 1996e; LLNL 1996h.

Table F.1.3–9. Emission Rates of Pollutants for the Vitrification Alternative

Pollutant	Hanford (kg/yr)	NTS (kg/yr)	INEL (kg/yr)	Pantex (kg/yr)	ORR (kg/yr)	SRS (kg/yr)
CO	72,000	72,000	72,000	72,000	72,000	72,000
NO_2	72,000	72,000	72,000	72,000	72,000	72,000
PM_{10}[a]	573	573	573	573	573	573
SO_2	1,845	1,845	1,845	1,845	1,845	1,845
Total suspended particulates[a]	573	573	573	573	573	573
Volatile organic compounds	14,500	14,500	14,500	14,500	14,500	14,500

[a] It is assumed that PM_{10} emissions are TSP emissions.

Source: LLNL 1996c.

Table F.1.3–10. Emission Rates of Pollutants for the Ceramic Immobilization Alternative

Pollutant	Hanford (kg/yr)	NTS (kg/yr)	INEL (kg/yr)	Pantex (kg/yr)	ORR (kg/yr)	SRS (kg/yr)
CO	250,000	250,000	250,000	250,000	250,000	250,000
NO_2[a]	660,000	660,000	660,000	660,000	660,000	660,000
PM_{10}[b]	770	770	770	770	770	770
SO_2	68.0	68.0	68.0	68.0	68.0	68.0
Total suspended particulates[b]	770	770	770	770	770	770
Volatile organic compounds	81	81	81	81	81	81

[a] The data report states the emission is NO_x but has been conservatively assumed to be NO_2.
[b] It is assumed that PM_{10} emissions are total suspended particulate emissions.
Source: LLNL 1996d.

Table F.1.3–11. Emission Rates of Pollutants for the Electrometallurgical Treatment Alternative

Pollutant	(kg/yr)
CO	42
NO_2[a]	191
PM_{10}[b]	15
SO_2	20
Total suspended particulates[b]	15
Volatile organic compounds	45

[a] The data report states the emission is NO_x but has been conservatively assumed to be NO_2.
[b] It is assumed that PM_{10} emissions are total suspended particulate emissions.
Source: LLNL 1996b.

Table F.1.3–12. Emission Rates of Pollutants for the Existing Light Water Reactor

Pollutant	Uranium Fuel (kg/yr)[a]	MOX Fuel (kg/yr)[b]
Criteria Pollutants		
CO	40.8	40.8
NO_2	114,307	114,307
PM_{10}[c]	8,755	8,755
SO_2	85,731	85,731
Total suspended particulates[c]	8,755	8,755
Toxic/Hazardous Pollutants		
Hydrocarbons	2,223	2,223

[a] [Text deleted.] Emissions rates from the partially completed LWR are representative for existing LWRs.
[b] No increase in nonradioactive air pollutant emission is expected. During operation, concentrations of criteria and toxic/hazardous air pollutants are expected to continue to be in compliance with Federal, State, and local air quality regulations or guidelines. No additional operation or testing of diesel generators or emissions from support facilities would be expected to occur from the use of MOX fuel. Pollutant concentrations from operating an existing LWR with a MOX core rather than a uranium core would not change. The process would remain the same, because criteria and toxic/hazardous emissions are not related to the type of fuel being used (NRC 1996b:2-22).
[c] It is assumed that PM_{10} emissions are total suspended particulate emissions.
Source: ORNL 1995b; derived from TVA 1974a.

Table F.1.3–13. ***Emission Rates of Pollutants for the Partially Completed Light Water Reactor***

Pollutant	(kg/yr)
Criteria Pollutants	
CO	40.8
NO_2	114,307
PM_{10}[a]	8,755
SO_2	85,731
Total suspended particulates[a]	8,755
Toxic/Hazardous Pollutants	
Hydrocarbons	2,223

[a] It is assumed that PM_{10} emissions are total suspended particulate emissions.
Note: Emission rates estimated for one operating unit.
Source: Derived from TVA 1974a.

Table F.1.3–14. ***Emission Rates of Pollutants for the Evolutionary Light Water Reactor***

Pollutant	Hanford (kg/yr)	NTS (kg/yr)	INEL (kg/yr)	Pantex (kg/yr)	ORR (kg/yr)	SRS (kg/yr)
CO	<45	<45	<45	<45	<45	<45
NO_2	2,630	2,630	2,630	2,630	2,630	2,630
PM_{10}[a]	0	0	0	0	0	0
SO_2	450	450	450	450	450	450
Total suspended particulates[a]	0	0	0	0	0	0

[a] It is assumed that PM_{10} emissions are total suspended particulates emissions.
Source: LLNL 1996g.

F.2 NOISE

This section summarizes local noise regulations and presents available sound level monitoring data for the sites. A discussion of operation noise sources and the potential for noise impacts is provided in PEIS Chapter 3, Affected Environment, and Chapter 4, Environmental Consequences. Any further analysis of operation noise impacts, including traffic noise impacts and impacts from outside sources, has been deferred to the tiered, site-specific *National Environmental Policy Act* documents.

The Occupational Safety and Health Administration standards for occupational noise exposure (29 CFR 1910.95) are applicable for worker protection at each site.

F.2.1 HANFORD SITE

Studies of noise at Hanford are discussed in Chapter 3 and in detail in *Hanford Site National Environmental Policy Act Characterization* (PNL-6415 Rev. 6, August 1994).

The State of Washington Department of Ecology has adopted regulations in Washington Administrative Code 173-60 through 173-70 which limit environmental noise levels. Maximum noise levels are defined for zoning of an area in accordance with Environmental Designation for Noise Abatement (EDNA). The Hanford Site is classified as a Class C EDNA on the basis of industrial activities. Unoccupied areas are also classified as Class C areas by default because they are neither Class A (residential) nor Class B (commercial). Maximum noise levels are established based on the EDNA classification of the receiving area and the source area (Table F.2.1–1) (HF PNL 1994a:4.144).

Table F.2.1–1. Applicable State Noise Limitations for Hanford Site Based on Source and Receptor Environmental Designation for Noise Abatement (dBA)

Source Hanford Site	Receptor Class A Residential	Receptor Class B Commercial	Receptor Class C Industrial
Class C - Day	60	65	70
Class C - Night	50	-	-

Source: HF PNL 1994a.

F.2.2 NEVADA TEST SITE

No environmental noise survey data are available for NTS. The State of Nevada and Nye County have not established any regulations that specify acceptable community noise levels with the exception of general prohibitions on nuisance noise.

F.2.3 IDAHO NATIONAL ENGINEERING LABORATORY

Studies of noise at INEL are limited primarily to noise measurements along roadways. These are discussed in Chapter 3 and in *NPR Environmental Impacts at the INEL: Air Quality, Cooling Towers, and Noise* (NPRD-90-059). The State of Idaho and the counties in which the INEL is located have not established any regulations that specify acceptable community noise levels, with the exception of general prohibitions on nuisance noise.

F.2.4 PANTEX PLANT

A study of sound levels near Pantex consists of data collected along roads for short periods of time during peak traffic and for specific noise events at Pantex. Neither the State of Texas nor the local government have established regulations that specify acceptable sound levels applicable to Pantex, with the exception of general prohibitions on nuisance noise.

F.2.5 OAK RIDGE RESERVATION

Sound level measurements have been recorded at various locations within and near ORR as discussed in Chapter 3 and documented by Cleaves (ORR 1991a:2) and Knazovich (ORR 1991a:6). Maximum allowable noise limits for the city of Oak Ridge are presented in Table F.2.5–1.

Table F.2.5–1. City of Oak Ridge Maximum Allowable Noise Limits Applicable to Oak Ridge Reservation

Adjacent Use	Where Measured	Maximum Sound Level (dBA)
All residential districts	Common lot line	50
Neighborhood business district	Common lot line	55
General business district	Common lot line	60
Industrial district	Common lot line	65
Major street	Street lot line	75
Secondary residential street	Street lot line	60

Note: dBA=decibel A-weighted.
Source: OR City 1985a.

F.2.6 SAVANNAH RIVER SITE

Ambient sound level data collected at SRS in 1989 and 1990 are summarized in *Sound-Level Characterization of the Savannah River Site* (NUS-5251). The States of Georgia and South Carolina, and the counties where SRS is located, have not yet established noise regulations that specify acceptable community noise levels except for a provision of the Aiken County Nuisance Ordinance that limits daytime and nighttime noise by frequency band (Table F.2.6–1).

Table F.2.6–1. Aiken County Maximum Allowable Noise Levels[a]

Frequency Band (Hz)	Nighttime Sound Pressure Levels[b]: Nonresidential Lot Line (dB)	Nighttime Sound Pressure Levels[b]: Residential Lot Line (dB)
20-75	69	65
75-150	60	50
150-300	56	43
300-600	51	38
600-1,200	42	33
1,200- 2,400	40	30
2,400-4,800	38	28
4,800-10,000	35	20

[a] Daytime (7:00 a.m. - 9:00 p.m.) sound pressure levels: apply one of the following corrections (dB) to the nighttime levels above: daytime operation only, +5; source operates less than 20 percent of any 1-hour period, +5; source operates less than 5 percent of any 1-hour period, +10; source operates less than 1 percent of any 1-hour period, +15; noise of impulsive character, -5; noise of periodic character, -5.

[b] For the purpose of this ordinance, nighttime is the period 9:00 p.m. to 7:00 a.m.

Note: dB=decibel.

Source: SR County 1991a.

F.2.7 ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

No sound level measurements have been made in the area near RFETS. Neither the State of Colorado nor the local government have established regulations that specify acceptable sound levels applicable to RFETS, with the exception of general prohibitions on nuisance noise.

F.2.8 LOS ALAMOS NATIONAL LABORATORY

No environmental noise survey data are available for LANL. The State of New Mexico has not established any regulation that specifies acceptable community noise levels with the exception of general prohibitions on nuisance noise.

Los Alamos County has adopted a noise ordinance that specifies maximum sound levels in residential areas. Sound levels at a residential property line are limited to 65 decibel A-weighted (dBA) during the hours 7 a.m. to 9 p.m., and to 53 dBA during the hours 9 p.m. to 7 a.m. The 65 dBA limit may be exceeded by up to 10 dBA for up to 10 minutes of any hour between 7 a.m. and 9 p.m.

Appendix G
Intersite Transportation

This appendix supplements Section 4.4. It describes the methodology used for intersite transportation risk analysis and provides estimated health risks from the transport of materials, historical shipment data for the affected sites, and other supporting documentation. Intrasite transportation of pits between Zone 4 and Zone 12 at Pantex to support storage of RFETS pits for the Preferred Alternative is described in Appendix Q.

G.1 TRANSPORTATION RISK ANALYSIS METHODOLOGY

G.1.1 TRUCK AND RAIL TRANSPORTATION RISK

This assessment addresses the intersite transport of plutonium (Pu), highly enriched uranium (HEU), cesium, Pu oxide (PuO_2), uranium oxide, mixed oxide fuel (MOX), low-level waste (LLW), transuranic waste, and immobilized material. Pu, including MOX fuel, and HEU would be transported in truckload shipments by safe secure trailer (SST). The other materials would be transported by commercial truck, except for immobilized Pu with radionuclides (vitrified glass logs, ceramic disks, or glass-bonded zeolite in canisters), which would be transported to a repository by rail. For overseas shipments, this assessment includes port handling and ocean transport. This assessment compares transportation impacts for the alternatives considered.

For this analysis, the isotopic composition of Pu was assumed to be 93 percent Pu-239, 6 percent Pu-240, and 1 percent other Pu isotopes. The isotopic composition of HEU was assumed to be 93 percent uranium-235. For the other radioactive materials to be transported, the isotopic compositions were estimated based on data provided from the facility designers.

Handling risk involves the loading and unloading of transport vehicles, which was estimated on a per-vehicle (truckload/rail carload) basis. One loading and unloading operation was assumed for each shipment. It was estimated that there would be two cargo handlers and 35 other workers within 50 meters (m) (164 feet [ft]) of the loading/unloading operations. Because of the low speeds, less than 8 kilometers per hour (km/hr) (5 miles per hour [mph]), involved in transferring Pu and uranium between a storage facility and the transport vehicles and because the rigid design standards used for the Type B packagings allow them to withstand an accident (for example, a fork lift puncture), it is extremely unlikely that a Type B package would be breached. The estimated probability of a package being damaged so severely (for example, by forklift puncture, high winds, or tornados) that the inner and outer containers would fail and some fraction of the contents would be dispersed is extremely low (that is, less than 1.0×10^{-12}). However, design-basis and beyond-design-basis accidents with frequencies in the range of 10^{-2} to 10^{-7} are evaluated under facility accidents. Detailed analyses and test results including a puncturing forklift accident which serves as a bounding value, are presented in Section M.5. The risk factor from transferring Pu and HEU between the storage facility and the transport vehicles is so low as to be inconsequential. Therefore, it is unlikely that a worker or member of the public fatality would occur as a result of an accident during the transfer of Pu or HEU. The collective dose due to accident-free radiological exposure to cargo handlers and other workers for each loading operation is estimated to be 0.06 person-roentgen equivalent man (rem) and 0.004 person-rem, respectively. Because the loading would occur onsite in a secure area, there would be no exposure to the public.

For the transportation analysis, materials were assumed to be in shippable forms that have been stabilized and packaged for shipment at the originating site and meet Department of Transportation (DOT), Nuclear Regulatory Commission (NRC), and Department of Energy (DOE) requirements. The health impacts from the transport of materials were estimated using an assumed population distribution along specific routes when sites were known or along an assumed route distribution of 84-percent rural, 15-percent suburban and 1-percent urban for generic sites; average container, truckload, or rail carload of material; and a standard unit of measure

for traffic fatalities (the risk per kilometer). Potential impacts are presented for both accident and accident-free scenarios.

The RADTRAN Version 4 computer code, developed and maintained by Sandia National Laboratories at Albuquerque, NM, was used to estimate health risks in terms of potential total fatalities from the transport of radioactive materials. The RADTRAN code combines user-determined demographic, transportation, packaging, and material factors with health physics data to calculate the expected radiological consequences of accident-free and accident transportation scenarios.

The transportation accident model in RADTRAN assigns accident probabilities to a set of accident categories. For the truck analysis, the eight accident-severity categories defined in NRC's *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NUREG-0170, December 1977) were used. The least severe accident category (Category I) represents low magnitudes of crush force, accident-impact velocity, fire duration, or puncture-impact speed. The most severe category (Category VIII) represents a large crush force, high accident-impact velocity, long fire duration, and high puncture-impact speed, such as an 88-km/hr (55-mph) collision into the side of the vehicle, and a 982 degrees Centigrade (°C) (1,800 degrees Fahrenheit [°F]) fire lasting 1.5 hr to produce a release of the material. The release fractions for Category VIII accidents were conservatively estimated to be 0.1 for the strictly controlled SST shipments and 1.0 for other shipments.

A unit dose per shipment was calculated using RADTRAN for each type of radioactive material to be transported between sites and for each alternative. The distance and fraction of rural, suburban, and urban population for each route was estimated using the INTERSTAT routing code for truck transport and INTERLINE for rail transport. These two routing codes are integrated with the RADTRAN code. For sea transport, the actual distance was used between an East Coast port (hypothetically, the U.S. Army port at Sunny Point, NC) to ports in the United Kingdom and France, 6,297 km (3,400 nautical miles) and 6,112 km (3,300 nautical miles), respectively. For land transport by SST to facilities without a specific site, a potential bounding risk was established for distances of 1,000 kilometers (km) (620 miles [mi]), 2,000 km (1,240 mi), and 4,000 km (2,480 mi), assuming rural, suburban, and urban population distributions of 84, 15, and 1 percent, respectively along the route. Under the European MOX fuel fabrication variant, the impacts from the transport of Pu materials from DOE origins (that is, existing storage, pit disassembly/conversion site, or Pu conversion site) to placement of the material aboard ship, were considered. For the assessment, the representative port was assumed to be at distances of 1,000 km (620 mi); 2,000 km (1,240 mi); or 4,000 km (2,480 mi) from the origin.

The transport index is a regulatory characteristic of a package and is equal to the radiation dose rate in mrem per hour at a distance of 1 m (3.3 ft) from the outside of the package (49 CFR 173.403). The transport index values were estimated to be the maximum allowed by regulatory requirements, as indicated by regulatory checks incorporated in RADTRAN. These regulatory checks limit the product of the number of packages and the transport index (of each package) to a value of about 16. This value was used as a bounding value for evaluating impacts. The quantity of material per package, number of packages per truckload, and number of truckloads (shipments) for the life of the project were based on estimates for each storage and disposition alternative.

To determine the transportation accident and accident-free impacts, the unit dose (the derived radiation dose for each shipment) was converted to a unit risk factor per shipment by multiplying the occupational accident-free dose by 4.0×10^{-4} cancers per person-rem and the public accident and accident-free dose by 5.0×10^{-4} cancers per person-rem (ICRP 1991a:22).

Nonradiological impacts from accident-free (air pollution) and highway accidents were also assessed. Fatalities from potential air pollution were estimated using 1.0×10^{-7} cancer fatalities per urban kilometer. Highway accident fatalities were estimated from national statistics using 1.5×10^{-8} rural, 3.7×10^{-9} suburban, and 2.1×10^{-9} urban for

occupational risks per km, and $5.3x10^{-8}$ rural, $1.3x10^{-8}$ suburban, and $7.5x10^{-9}$ urban for nonoccupational risks per km (SNL 1986a:167). The combined resultant health risks are presented as potential fatalities.

The estimated impacts for each alternative were derived by summing the health effects for the materials to be transported for each transportation segment required by the alternative.

G.1.2 RISK ASSOCIATED WITH PORT HANDLING AND GLOBAL COMMONS FOR EUROPEAN MIXED OXIDE FUEL FABRICATION

For the Existing Light Water Reactor Alternative, MOX fuel could be produced in existing European facilities to meet interim needs, pending availability of a domestic MOX fuel fabrication plant. Therefore, this programmatic environmental impact statement (PEIS) considered transportation impacts at the ports and global commons. The methodologies for the various cases are explained in the following sections.

G.1.2.1 Port Transit and Intermodal Handling Analysis (Accident-Free Conditions)

The materials to be shipped under this action (Pu oxides and fresh MOX fuel assemblies) emit low radiation levels. Consequently, the self-shielding and the shielding afforded by the external walls of the shipping containers are sufficient to reduce the estimated maximum dose rate at 1 m (3.3 ft) from the package to zero for the 6M package (with 2R inner container) and to less than $1.5x10^{-4}$ millirem/hr for the MO-1 package. [Text deleted.]

G.1.2.2 Port Transit and Intermodal Handling Analysis (Accident Conditions)

For the shipment of Pu oxide from lag storage to an overseas MOX fuel fabrication site and the return shipment of reactor fuel assemblies, (1) material would be transported by SST to or from the selected U.S. port and (2) shipping containers would be transferred between the SST and the ships. The Pu oxide would be contained in 6M-2R, Type B packaging which would be placed in groups of eight or fewer packages in a cargo restraint transporter (CRT) to facilitate loading and securing in the SST. For ship transport, the 6M-2R packagings would be placed in International Standards Organization (ISO) intermodal containers that are compatible with the common handling and securing facilities available. The returning fuel assemblies would be shipped in MO-1 casks that meet Type B certification requirements.

The shipping schedule projects two shipments of Pu oxide per year and a maximum of four shipments of fresh MOX fuel assemblies per year. Facilities for transferring CRTs from the SST to the ISO containers and staging of returning fuel casks unloaded from ships to multiple SST convoys would be available in the immediate port area. Handling and short-term storage in these facilities do not involve significant accident risks apart from the remote possibility of a major fire. All other mishaps that might occur during the shipping, handling, and inspection operations are subsumed in the accident rate per port transit of a ship, which is described in Section G.1.2.3. Transportation risks associated with SST operations are treated separately.

During port transit, loading, and unloading, the occurrence probability of an accident of any type can be assigned from reported statistics. In this analysis, all accidents involving a container breach and fire on a ship are modeled as occurring at pier side. This approach is highly conservative in that it ignores both the high probability of a greater stand-off distance and the fact that transits to ports are typically through low population density areas. Additionally, in the absence of prevailing wind data, the radioactive cloud (plume) is modeled as traveling over the port area and out to a distance of 80 km (50 mi). In reality, the prevailing winds might blow the plume away from populated areas. Without detailed population density data, the accident model treats the port population density as continuing out for the full 80 km (50 mi).

G.1.2.3 Modal Considerations

Maritime accident rate data indicate that the basic accident rate in and near ports is approximately 3.0×10^{-4} per port transit; that is, three accidents per 10,000 port visits (DOE 1991s:22). The conditional occurrence probabilities of each accident severity have been developed as well. A conditional probability is defined as the probability, given that an accident has occurred, that it will be of a certain severity. In order to calculate overall probability of an accident of a particular severity, the base accident probability (accident rate) must be multiplied by the conditional probability. For Type B packages containing the materials contemplated in this action (Pu oxide and fresh MOX fuel assemblies), the highest conditional probability, for an accident resulting in the release of package contents, yields an overall maximum accident probability of 5.0×10^{-9} per port transit (DOE 1996n:D-191; SNL 1995b:3). The resultant overall probability is, therefore, approximately 3.0×10^{-8}/year (yr) (that is, number of accidents per transit multiplied by number of transits per year [six]).

Activities or conditions that affect material release from packages in the event of an accident include, but are not limited to, the following:

- **Container Drops During Intermodal Transfer.** Berths at all ports considered in this action are likely to consist of either concrete aprons constructed on friction pilings driven into the sediment or tamped earth contained within sheet pilings and surfaced with concrete. Both are yielding surfaces, and the water and the deck of a ship are even more yielding than a dock surface. Previous studies have shown that a Type B package can be dropped onto a yielding surface from at least 10 m (30 ft) (as specified for Type B packaging) without sustaining damage (IAEA 1987a:551; SNL 1975a:7,15). Information describing Type B package testing is contained in Section G.5.

  Container drops are infrequent, and such a drop would be considerably less severe than the certification drop test conditions, even if the container was dropped from greater than 10 m (30 ft), because of the yielding nature of the surfaces onto which they might fall. Therefore, container drops during intermodal transfers are not considered a threat to Type B packaging, and they need not be considered further in this analysis. Since truck velocities within the immediate confines of a port are low and container movements are preceded by a port authority police escort vehicle, truck accidents in port also are not considered further. Port accidents that are considered consist mainly of vessel accidents, including accidents in which a moored ship is struck, usually by another ship (SNL 1980a:4-1,4-2).

- **Packaging Response to Thermal Conditions.** The packaging considered for this action is designed to survive the thermal load specified in the Type B packaging certification tests with no release of contents. Total heat input to a package is more important than peak temperature. A fire that meets or exceeds the regulatory fire temperature of 800 °C (1,470 °F) may have no effect whatsoever on the package if it does not engulf the cask (that is, if it does not satisfy the test condition of the entire package being exposed to the fire) and/or if it does not last at least as long as the 30 minutes specified in the regulatory test (NRC 1987b:2-24).

  The likelihood that a shipboard fire will occur in the same location as the cargo is relatively small; many ship fires are confined to engine rooms, galleys, etc., and do not affect cargo areas (SNL 1980a:4-19). Fire-duration is also unlikely to be a factor. Although shipboard fires have been described as burning for days, that is not, by itself, sufficient information to determine whether any particular location as small in volume as a single container is exposed to fire at all, much less "for days." Indeed, shipboard fires are often traveling fires, which progress through a ship during the course of a fire and during which no single location in the fire's path is exposed for a prolonged period of time. Fires involving tanker ships are not directly relevant to conditions onboard container ships; tanker fires are discussed in *Tanker Accident Rates and Expected Consequences in U.S. Ports*

and High Seas Regions (TRB 1985a:164). In a rare historical accident involving the collision of an oil tanker and a cargo ship, conditions onboard the tanker and container ships were quite different (DOT 1975a:1; NTSB 1975a:1).

- **Atmospheric Dispersal.** Atmospheric dispersal is usually the means of spreading any material released during a severe accident beyond the immediate vicinity and into the human environment. Dispersal is affected by the degree of turbulence in the atmosphere, which can vary from unstable (Class A) to extremely stable (Class F). The Pasquill system of atmospheric stability classes is commonly used to describe this variation, although there are other systems (NRC 1983a:2-18). A conservative representation of atmospheric conditions at ports generated by the DIFOUT dispersion code for Class D, which has been used in previous port analyses, was used for this analysis (SNL 1969a:19).

G.1.2.4 Port Handling Impacts

Accident-risk estimates were calculated using the RADTRAN 4 computer code. Overall probabilities for accidents of sufficient severity to release radioactive materials to the environment during a port transit and associated handling were obtained from "Radiological Consequences of Ship Collisions That Might Occur in U.S. Ports During the Shipment of Foreign Research Reactor Spent Nuclear Fuel to the United States in Break-Bulk Freighters." Package releases were modeled in accord with shipment of powdered material of fissile assemblies (taking account of their unirradiated state). Since specific ports have not been identified, population density in the vicinity of a nominal port was set at a mean urban value of 3,861 square kilometers (10,000 square miles), which is very conservative for most U.S. ports. Impacts, calculated in terms of dose risk and latent cancer fatalities, for all shipments in 1 year (2 export; 4 import) are presented in Table G.1.2.4–1 together with the separate export and import risks. The health risks are based on a value of 5.0×10^{-4} fatalities per person-rem for the general public (workers are included with the public for accident conditions).

If any of the alternatives in the reactor category were selected, MOX fuel would have to be fabricated. No decision has been made as to where MOX fuel would be fabricated or to where the fuel would be transported for use. However, if the decision were to make any of the MOX fuel in Europe, DOE would ship Pu by sea through ocean ports and would receive MOX fuel shipped by sea from Europe, again through ocean ports. The selection of which ports, after additional environmental reviews under NEPA, would be part of the larger DOE transportation planning process that would also determine shipment schedules, port or ports of entry and exit, modes of transport to and from the ports, emergency preparedness plans and contacts, and communications strategies based on current capabilities. Because there is uncertainty associated with the future nature of port activities and their capabilities for handling Pu and MOX fuel 10 or more years into the future, no specific ports were analyzed for this PEIS. For determining the distance between a port on the eastern U.S. coast and a port in the Great Britain or France, Sunny Point, NC, was used. The distance between Sunny Point, NC, and the European ports is stated in Section G.1.1.

In selecting transportation routes, including any ports, the safety of the public and security of the cargo are of primary consideration. To ensure these primary considerations are achieved, DOE would evaluate the ports to be used based on a set of criteria that would include adequacy of harbor and dock characteristics to satisfy the Pu container carrying ship requirements; adequacy of facilities for safe receipt, handling, and transhipment of Pu and MOX fuel; overall port security; availability of safe and secure lag storage; adequacy of overland transportation systems from ports to the reactor and from the Pu site(s); availability of a skilled labor force with routine experience in safe and secure handling of hazardous cargo; emergency preparedness status and response capabilities at the port and the nearby communities; quality of intermodal access for truck or rail shipments to and from the port; proximity to the proposed pit disassembly/conversion facility and reactor sites; local restrictions or regulations on movement of hazardous cargo; absence of significant environmental restrictions from the port; and the size of human population at the ports and along transportation routes.

Table G.1.2.4–1. Annual Accident Risks Due to Export of Plutonium Oxide and Import of Mixed Oxide Fuel

	Annual Shipments	Annual Dose-Risk (person-rem)	Health Effect[a]
PuO_2–export	2	3.3	$1.6x10^{-3}$
MOX fuel–import	4	$3.6x10^{-7}$	$1.8x10^{-10}$
Total annual effect		3.3	$1.6x10^{-3}$

[a] Estimated latent cancer fatalities per year.
Source: RADTRAN model results.

The total health risk of $1.6x10^{-3}$ latent cancer fatalities per year is a highly conservative estimate, as the population density surrounding actual ports may be smaller by as much as a factor of 10. Also, one-half of the 6M-2R packages in the particular ship hold impacted during an accident are modeled as being affected in severe accidents; this is considered to be very unlikely. The major reason the risk associated with the PuO_2 shipments is higher than that for the MOX fuel is the physical state of the material, a fine powder, which is 100 percent dispersible upon release. If the PuO_2 is shipped as pellets, as in the case for fuel rods, the annual risk for the PuO_2 shipments is reduced to $1.6x10^{-7}$person-rem or $8.2x10^{-11}$ latent cancer fatalities.

G.1.2.5 Effects on the Global Commons

European MOX fuel fabrication, which could be used on a short-term basis to provide lead test assemblies and other MOX fuel, would option involves the shipment of Pu oxide on an ocean-going vessel to Europe, where it would be fabricated and loaded into MOX fuel assemblies and returned by ship to the United States. The frequency of a severe maritime accident, sufficient to release radioactive materials resulting in catastrophic consequences, is less than $1.0x10^{-6}$/yr. Nevertheless, this discussion addresses concerns that could arise over potential impacts to the global commons from an accident involving the shipment of Pu oxide or MOX fuel.

However unlikely, there is always a potential for maritime accidents during the ocean shipment of Pu and MOX fuel. The severity of maritime accidents ranges from immersion to collision to fire and collision. Accidents in the port egress areas have a greater potential for public consequences than accidents on the open seas because of the proximity to populated areas. Studies performed for recent *National Environmental Policy Act* (NEPA) of 1969 documents conclude that the probability of a maritime accident of sufficient severity to cause significant release of radioactive materials resulting in catastrophic consequences is extremely small, on the order of $1.0x10^{-8}$ per port call (DOE 1993x:A-3) to $1.0x10^{-9}$ per port call (DOE 1996n:D-191). Assuming six shipments per year, the probability of a maritime accident would be in the order of $1.0x10^{-7}$/yr to $1.0x10^{-8}$/yr.

An environmental assessment of the import of Russian Pu-238 shows that collision accidents on the open seas are more severe than those in inland waterways because of higher speeds, but less frequent because of lighter ship traffic (DOE 1993x:A-2). As a vessel nears port, it enters more congested waters and its speed decreases, but accident frequencies increase because of the increased ship traffic and relative proximity of one vessel to another. If PuO_2 were to be released in water in port areas or open seas, the study indicates that the oxide nature of the fuel results in a very low dissolution rate; and the aquatic chemistry of Pu is such that it preferentially binds with the sediment rather than remaining dissolved (DOE 1993x:A-3). The DOE study concluded that fire alone is not a credible means of causing a release, and any accident sequence that resulted in a release of contents must include exposure of the package containing the Pu to mechanical forces great enough to cause failure (that is, forces greater than required in Federal certification testing) (DOE 1993x:A-4). The probability of a severe ship collision, followed by a fire, is on the order of $1.0x10^{-8}$ per port call (DOE 1993x:A-3). Although the environmental assessment studies were performed specifically for the shipment of Pu-238, the results and conclusions are considered generally applicable to the shipment of Pu-239 and MOX fuel.

G.1.2.6 Security Considerations in the Global Commons, and at European MOX Facilities

The elements of security measures would be incorporated in the transportation plan DOE would complete for the shipment of PuO_2 to European MOX fuel fabrication sites, and for the return of fresh MOX fuel assemblies. The movement of these materials in the United States is addressed in Section 4.4.2.2 on the use of the SST transportation system. The safeguarding of the Pu to be shipped—from the time it leaves the SST in 6M-2R, Type B packaging in CRTs, through its loading into ISO containers, movement by port facility tractors, staging in the dock facilities, movement to its transport location on board, and unloading, staging, handling, and shipment to the MOX fuel fabrication facilities—would be addressed in the procedures specified in a transportation plan that DOE would prepare in accord with its guidance documents. This transportation plan would also address compliance with DOT, NRC, International Atomic Energy Agency (IAEA) regulations, safeguards and standards, and any additional measures deemed necessary to ensure that the transportation would be carried out in the most secure manner, considering the relative risks involved, and that recovery measures adequately mitigate the consequences in the event that security is breached. The DOT is the U.S. Competent Authority designated to carry out the provisions of the IAEA standards, and DOE would be responsible for the transportation plan to address the entire Pu transportation system for this campaign, from the point of origin in the United States to the delivery of the MOX fuel assemblies. In addition, the transportation plan would address Federal, State, and local regulations of the country where the MOX fuel fabrication facility is located.

Physical security of the Pu in transit would be provided in compliance with a security system referred to in the transportation plan. The DOT and NRC are responsible for the assessment of security measures for ship transport. The security system would include procedures for coping with circumstances that pose a threat to the Pu shipments and with other safeguards emergencies, and instructions for surveillance and escort requirements. These procedures would address the detection of abnormal presence of unauthorized persons, vehicles, or vessels in the vicinity of PuO_2 or MOX fuel shipments; the monitoring of the progress of the shipments; the notification of requirement for emergency actions; the maintenance of records required for verification that security has not been breached; and the documentation that proper procedures have been followed. Arrangements would be made with authorities at ports, and those along the routes to the MOX fuel fabrication facility responsible for responding to a security event or call for assistance. These arrangements would be approved in advance by the NRC, DOT, and State and local authorities. A shipment vessel in port would be protected by two armed escorts stationed on board or on the dock at a location permitting observation of the shipment. At sea, an authorized ship's officer would be responsible for providing the appropriate level of security and maintaining communication with the NRC.

The physical security threat to spent nuclear fuel in transport was recently evaluated by DOE in the *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Fuel* (DOE/EIS-0218, Volumes 1 and 2, Appendices D and H). The environmental impacts evaluated therein resulting from accidents and malicious attacks (explosion, breach of containment, fire) are relevant to the shipment of MOX fuel. Those analyses indicate that the consequences of the act to breach the packaging containment (explosions, penetration, fire) create a much higher injury and health risk than the release of the radioactive materials from the package. The packaging is designed so that the Pu is not present in sufficient quantities to create a nuclear criticality in the event of breach of the package containments. A nearby explosion unrelated to the Pu would not release Pu from the packages, and a penetration device (shaped charge, armor piercing projectiles) would most likely only rupture a single container, thus severely limiting the radioactive material hazard resulting from a malicious destructive act. The accident analyses described in this appendix address the risks associated with accidents resulting from a breach of security during transportation of PuO_2 and MOX (DOE 1996n:D-252–D-256; H-8–H-10).

Additional information on the shipment of Pu by sea can be found in *Safety of Shipments of Plutonium by Sea*, DOE/EM-0103, September 1993. This document was completed by DOE pursuant to Section 2904 of the *Energy Policy Act* of 1992, and addresses the shipment of Pu from one foreign port to another, and cites the conventions, treaties, and practices under which such shipments have been carried out and the codes and

standards used to ensure the safe and secure transport of Pu by sea. It notes that the shipment of Pu from France to Japan was done on a dedicated special purpose vessel that was accompanied by an armed escort ship capable of providing emergency support to the transport vessel.

For actions associated with this PEIS, transport of Pu by ship would be done by dedicated British Nuclear Fuel, Limited or COGEMA ships from military seaports in the United States to seaports in Great Britain or France. The transport would meet applicable IAEA requirements and the International Maritime Organization code. While in temporary storage at the seaports and during transport on the ship, appropriate escort security measures would be implemented.

G.2 HISTORICAL INTERSITE TRANSPORTATION SHIPMENT DATA

Table G.2–1 presents a 5-year (1990 through 1994) summary of the nonhazardous and hazardous cargo shipped by commercial carriers to and from each of the eight DOE sites included in this PEIS.

Table G.2–2 presents a summary, by chemical name, of all hazardous material shipped to and from Hanford Site, Idaho National Engineering Laboratory, Los Alamos National Laboratory, and Nevada Test Site for 1994. Table G.2–3 present a summary, by chemical name, of all hazardous material shipped to and from Oak Ridge Reservation, Pantex Plant, Rocky Flats Environmental Technology Site, and Savannah River Site for 1994.

G.3 HIGHWAY DISTANCE

Table G.3–1 shows the highway distance between the eight DOE sites being evaluated.

G.4 TRANSPORTATION EQUIPMENT

Packaging refers to a container and all accompanying components or materials necessary to perform its containment function. Packagings used by DOE for hazardous materials shipments are either certified to meet specific performance requirements or built to specifications described in DOT hazardous materials regulations (49 *Code of Federal Regulations* [CFR] Subchapter C). For relatively low-level radioactive materials, DOT Specification Type A packagings are used. These packagings are designed to retain their contents under normal transportation conditions. More sensitive radioactive materials shipments require use of highly sophisticated Type B packaging, designed and tested to prevent the release of contents under all credible transportation accident conditions.

Plutonium and HEU are DOE-unique hazardous materials that require special protection. In addition to meeting the stringent Type B containment and confinement requirements of the NRC's 10 CFR 71 and DOT's 49 CFR, packaging for nuclear weapons and components must be certified separately by DOE. DOE employs a closed, Government-owned and -operated Transportation Safeguards System for the intersite transport of nuclear weapons and components, including Pu and HEU. Specially designed SSTs are utilized to ensure high levels of safety and physical protection. Limited-life components are transported almost exclusively by DOE's contract air carrier.

As a representation of a typical Type B packaging used to transport weapons components, the testing sequence for the 6M, Type B packaging used for the shipment of HEU is described below. Pu packaging requires a similar, high level of protection. Most other radioactive and hazardous materials, such as LLW, would be transported by commercial truck. Figures G.4–1 through G.4–6 illustrate packaging types and a CRT used for the transport of materials.

Table G.2–1. Five-Year Summary of Cargo Shipments by Commercial Carrier To and From Department of Energy Sites

	1990		1991		1992		1993		1994	
Site	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)
Hanford										
Hazardous	1,434	6,900,276	970	6,987,898	1,138	2,703,286	1,069	1,475,251	1,170	1,348,258
Nonhazardous	44,535	42,740,651	48,881	42,828,946	60,301	32,069,447	71,303	38,498,165	74,448	15,414,828
All cargo	45,969	49,640,927	49,851	49,816,844	61,439	34,772,733	72,372	39,973,416	75,618	16,763,086
INEL										
Hazardous	1,598	19,601,146	1,672	23,719,753	1,641	18,553,980	1,864	22,006,964	1,852	16,108,334
Nonhazardous	31,150	19,774,939	34,586	10,824,950	37,379	12,590,160	40,122	19,569,410	41,419	11,825,648
All cargo	32,748	39,376,085	36,258	34,544,703	39,020	31,144,140	41,986	41,576,374	43,271	27,933,982
LANL										
Hazardous	851	544,668	680	316,974	1,089	363,818	1,133	345,403	692	214,510
Nonhazardous	28,266	4,129,802	28,757	3,943,075	36,805	1,855,129	46,663	2,617,906	49,453	3,327,743
All cargo	29,117	4,674,470	29,437	4,260,049	37,894	2,218,947	47,796	2,963,309	50,145	3,542,253
[Text deleted.]										
NTS										
Hazardous	1,742	20,627,008	1,325	15,777,433	1,432	17,834,469	1,143	15,845,750	1,324	22,384,272
Nonhazardous	23,107	38,455,253	21,898	36,197,342	19,938	31,944,034	16,568	10,622,714	14,839	21,567,339
All cargo	24,849	59,082,261	23,223	51,974,775	21,370	49,778,503	17,711	26,468,464	16,163	43,951,611
ORR										
Hazardous	2,141	3,592,513	1,433	2,254,290	3,896	8,546,187	3,130	11,765,312	3,169	6,438,748
Nonhazardous	55,921	8,176,837	57,217	6,905,370	69,771	7,448,941	74,479	5,409,370	75,684	7,409,628
All cargo	58,062	11,769,350	58,650	9,159,660	73,667	15,995,128	77,609	17,174,682	78,853	13,848,376
Pantex										
Hazardous	1,869	407,622	1,339	462,842	1,124	601,087	1,080	597,720	612	328,329
Nonhazardous	8,494	1,262,617	10,085	1,314,989	10,191	1,317,023	11,135	1,733,062	11,760	1,732,379
All cargo	10,363	1,670,239	11,424	1,777,831	11,315	1,918,110	12,215	2,330,782	12,372	2,060,708
RFETS										
Hazardous	1,031	9,063,839	620	3,072,285	553	3,394,375	640	3,409,414	671	3,389,440
Nonhazardous	14,841	5,749,752	15,409	4,284,776	14,427	4,002,657	13,555	4,573,259	13,612	4,204,062
All cargo	15,872	14,813,591	16,029	7,357,061	14,980	7,397,032	14,195	7,982,673	14,283	7,593,502

Table G.2–1. Five-Year Summary of Cargo Shipments by Commercial Carrier To and From Department of Energy Sites—Continued

Site	1990		1991		1992		1993		1994	
	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)
SRS										
Hazardous	1,151	4,049,534	643	3,192,682	1,462	2,625,821	1,386	2,508,277	1,147	2,754,435
Nonhazardous	36,012	227,513,797	33,870	151,211,460	34,348	136,905,940	34,816	224,005,944	25,915	241,279,894
All cargo	37,163	231,563,331	34,513	154,404,142	35,810	139,531,761	36,202	226,514,221	27,062	244,034,329

Note: Gross weight includes the weight of the package.
Source: SAIC 1995a:1.

Table G.2–2. Summary of Hazardous Materials Shipped To and From Department of Energy Sites–1994

Commodity	Hanford		INEL		LANL		NTS	
	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)
Acetylene gas	1	22			1	95		
Aluminum nitrate	2	1,087	9	152,335			2	144
Aluminum sulfate, solid	1	4,798	1	3	1	142		
Ammonia, anhydrous	6	242	4	383	1	41	1	1,487
Ammonium fluoride								
Ammonium hydroxide			3	44				
Ammonium sulfate			1	3			1	13
Argon	11	1,313	2	284	3	354	20	5,975
Asbestos articles	2	5,516	2	1	1	1		
Asphalt			1	513			6	3,288,218
Beryllium metal					1	3		
Beryllium metal or powder								
Cadmium nitrate			3	23				
Cadmium sulfate			1	3				
Calcium nitrate			1	142				
Chlorine	11	17,824	5	429	1	3	1	5,670
Class A poison	13	590	4	190	3	18	2	296
Class B poison	5	2,900	1	107				

Table G.2–2. Summary of Hazardous Materials Shipped To and From Department of Energy Sites–1994—Continued

Commodity	Hanford Shipments (number)	Hanford Gross Weight (kg)	INEL Shipments (number)	INEL Gross Weight (kg)	LANL Shipments (number)	LANL Gross Weight (kg)	NTS Shipments (number)	NTS Gross Weight (kg)
Combustible liquid, n.o.s.	9	3,592	9	346	6	1,529	10	55,477
Corrosive material, n.o.s.	116	106,517	222	157,841	28	2,458	29	6,205
Dry ice	4	19			49	427		
Empty haz. cntrs. (Non-ram)	10	2,463	2	6,078			76	292,447
Enriched boric acid			2	817				
Env haz. subst. (Marine pollutant)							1	5,443
Env. hazardous substance	4	162	3	59				
Etiologic agent, n.o.s.					1	4		
Explosives, n.o.s. (Class 1.1)			2	349	8	426	3	4,891
Explosives, n.o.s. (Class 1.2)								
Explosives, n.o.s. (Class 1.3)								
Explosives, n.o.s. (Class 1.4)	2	148	3	1,195	7	376		
Ferrous sulfamate							1	5
Ferrous sulfate			1	2				
Flammable gas, n.o.s.	24	2,664	21	7,298	43	35,757	3	178
Flammable liquid, n.o.s.	97	28,101	102	31,629	23	4,162	21	2,169
Flammable solid, n.o.s.	1	51	12	18,586	14	285	2	214
Fluoboric acid								
Fuel oil (Diesel, 1-6, etc.)			336	9,681,302	5	7,146	122	4,093,274
Gasoline			60	1,592,185	1	2	94	2,741,403
Hazardous waste (Non-ram)	1	7,258			1	66	2	12
Helium	20	7,145	13	2,326	27	18,439	5	1,278
Hydrocarbon gas, compressed or liquefied								

Table G.2–2. Summary of Hazardous Materials Shipped To and From Department of Energy Sites–1994—Continued

	Hanford		INEL		LANL		NTS	
Commodity	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)
Hydrochloric acid	14	910	10	35	2	2,169	5	724
Hydrofluoric acid			1	5			3	633
Hydrofluoric acid solution, spent	3	256	1	481	1	1	3	74
Hydrogen gas	2	181			1	33		
Hydrogen peroxide	6	8,216	1	32			2	343
Irritant, n.o.s.					2	2		
Isobutane, compressed or liquefied					2	1,134	1	3
Lithium metal	6	224	1	1	3	5		
Lubricating oil			39	2,826	2	182	33	31,307
Magnesium, powder, metal strip					2	11		
Mercuric nitrate					1	15	1	1
Methanol, liquid							1	40
Methyl isobutyl ketone			3	4,193			7	150,547
Misc. hazardous material			3	1,341				
N-dodecane								
Natural gas, compressed or liquefied							1	1,270
Nitric acid (incl. fuming)	25	3,167	9	614	1	1	5	1,098
Nitric acid (over 40%)	1	40	2	43,500			1	334
Nitric acid, fuming	3	291						
Nitrogen	4	3,606	110	1,623,986	8	277	20	14,370
Non-flammable gas, n.o.s.	145	62,388	122	13,025	91	28,603	25	16,682
Organic peroxide, n.o.s.	1	1	1	1	1	1,194		
Orm A, n.o.s.								
Orm B, n.o.s.								
Orm D, consumer commodity			2	554				

Table G.2–2. Summary of Hazardous Materials Shipped To and From Department of Energy Sites–1994—Continued

	Hanford		INEL		LANL		NTS	
Commodity	**Shipments (number)**	**Gross Weight (kg)**	**Shipments (number)**	**Gross Weight (kg)**	**Shipments (number)**	**Gross Weight (kg)**	**Shipments (number)**	**Gross Weight (kg)**
Orm E, n.o.s.			1	7,521				
Other regulated material, liquid			4	269				
Other regulated material, solid			9	660			3	3,612
Oxidizer, n.o.s.	91	11,693	18	1,363	4	3,023	5	271
Oxygen	9	1,273	19	289,616	3	166	4	704
Poison, liquid, n.o.s.	7	400	29	1,375	9	1,026		
Poison, solid, n.o.s.	14	235	15	587	7	98	1	19
Propane, compressed or liquefied			1	21	1	272	2	158
RAM, empty pkgs	30	156,726	41	224,474	49	35,462	1	1,016
RAM, fissile, <20% U-235								
RAM, fissile, >20% U-235								
RAM, fissile, HRCQ	3	65,317						
RAM, fissile, HRCQ, IR PINS			1	100				
RAM, fissile, HRCQ, UNIR PINS	1	21,772						
RAM, fissile, n.o.s.	1	73	5	17,327	10	669		
RAM, fissile, UNIR PINS			9	63,539				
RAM, fissile, waste								
RAM, HRCQ, special	7	107,002						
RAM, instr. & articles	25	688	2	41	1	154		
RAM, LSA, n.o.s.	6	14,590	101	866,798	5	4,651		
RAM, LSA, UF_6					1	277		
RAM, LSA, waste	34	443,212					688	11,291,791
RAM, ltd. quant, n.o.s.	161	5,429	234	785,852	124	3,257	3	3,570
RAM, medical isotopes					6	31		
RAM, n.o.s.	131	28,340	80	225,191	75	21,660	25	2,169
RAM, n.o.s., HRCQ			2	13,395	1	16,329		

Table G.2–2. Summary of Hazardous Materials Shipped To and From Department of Energy Sites–1994—Continued

	Hanford		INEL		LANL		NTS	
Commodity	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)
RAM, n.o.s., special	27	2,338	91	38,863	5	3,889	8	5,708
RAM, n.o.s., waste	12	161,664						
RAM, U-metal, pyrop					1	1		
RAM, UO_x, n.o.s.			1	1				
Small arms ammunition			1	36			1	387
Sodium hydroxide (caustic soda)	13	28,331	13	77,621	7	8,218	7	8,389
Sodium metal, (non-RAM)	3	315	5	44				
Sodium nitrate	10	1,667			1	5	1	3
Spontaneously combustible material	3	4	3	30	3	47		
Sulfuric acid	9	23,408	13	141,353	2	403	1	1
Toxic gas, inhalation hazard	13	284	7	655	26	7,500		
Trichloroethane 1,1,1			2	220				
Wet cell batteries	10	1,804	14	6,322	9	2,013	64	344,251
Total	1,170	1,348,257	1,852	16,108,341	692	214,512	1,324	22,384,272

Note: Gross weight (kg) includes the weight of the package; n.o.s.=not otherwise specified.

Source: SAIC 1995a:2.

Table G.2–3. Summary of Hazardous Materials Shipped To and From Department of Energy Sites–1994

	ORR		Pantex		RFETS		SRS	
Commodity	**Shipments (number)**	**Gross Weight (kg)**	**Shipments (number)**	**Gross Weight (kg)**	**Shipments (number)**	**Gross Weight (kg)**	**Shipments (number)**	**Gross Weight (kg)**
Acetylene gas	13	8,101			5	1,714	17	3,372
Aluminum nitrate	1	5			1	2	2	53
Aluminum sulfate, solid	1	378			1	962	2	6,277
Ammonia, anhydrous	3	686			2	252	4	587
Ammonium fluoride	1	1						
Ammonium hydroxide			1	34	4	397		
Ammonium sulfate								
Argon	199	430,223	8	1,250	48	797,649	33	82,713
Asbestos articles	33	37,544						
Asphalt			1	540	1	16		
Beryllium metal								
Beryllium metal or powder	1	6,638						
Cadmium nitrate	1	489			2	7		
Cadmium sulfate								
Calcium nitrate	1	1	1	2	3	16		
Chlorine	35	63,200	4	1,780	3	895		
Class A poison	2	10						
Class B poison	2	3,680	2	1,343				
Combustible liquid, n.o.s.	28	2,237	7	1,142	11	186	3	119
Corrosive material, n.o.s.	183	213,634	60	15,996	32	5,654	120	290,507
Dry ice	153	45,406			33	496		
Empty haz. cntrs. (non-RAM)	210	576,434						
Enriched boric acid								
Env haz. subst. (marine pollutant)	3	80					1	20
Env. haz. subst.	10	4,934			2	302		
Etiologic agent, n.o.s.	1	144						
Explosives, n.o.s. (Class 1.1)			27	25,058				

Table G.2–3. Summary of Hazardous Materials Shipped To and From Department of Energy Sites–1994—Continued

	ORR		Pantex		RFETS		SRS	
Commodity	**Shipments (number)**	**Gross Weight (kg)**	**Shipments (number)**	**Gross Weight (kg)**	**Shipments (number)**	**Gross Weight (kg)**	**Shipments (number)**	**Gross Weight (kg)**
Explosives, n.o.s. (Class 1.2)			1	40			5	29,821
Explosives, n.o.s. (Class 1.3)			2	2,650				
Explosives, n.o.s. (Class 1.4)	7	3,870	93	14,008	6	6,588	8	4,859
Ferrous sulfamate	1	2,749	1	21				
Ferrous sulfate	2	2,041						
Flammable gas, n.o.s.	42	24,301	13	1,734	4	4,621	25	57,028
Flammable liquid, n.o.s.	140	54,056	54	6,947	20	1,278	33	28,406
Flammable solid, n.o.s.	35	360	58	6,068	1	11	1	7
Fluoboric acid	1	1						
Fuel oil (diesel, 1-6, etc.)	109	366,209			37	434,956	3	2,188
Gasoline	166	624,837			37	763,986	10	4,790
Hazardous waste (non-RAM)	3	12	1	19	2	8,865	8	1,438
Helium	33	42,913	11	640	9	104,851	21	27,444
Hydrocarbon gas, compressed or liquefied								
Hydrochloric acid	16	95	6	20	19	1,735	25	43,606
Hydrofluoric acid	2	59			3	284	7	6,885
Hydrofluoric acid solution, spent	1	4			2	495	1	27
Hydrogen gas	11	39,032	3	217	2	1,062	13	2,620
Hydrogen peroxide	8	1,911	1	2	2	54	9	3,870
Irritant, n.o.s.								
Isobutane, compressed or liquefied	2	1						
Lithium metal	24	3,290	9	845				
Lubricating oil	13	1,589	14	3,766	1	260	22	8,391
Magnesium, powder, metal strip	10	6					1	39

Table G.2–3. Summary of Hazardous Materials Shipped To and From Department of Energy Sites–1994—Continued

	ORR		Pantex		RFETS		SRS	
Commodity	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)
Mercuric nitrate								
Methanol, liquid	1	1			3	26	1	123
Methyl isobutyl ketone								
Misc. hazardous material	19	653	1	13	1	8	1	75
N-dodecane								
Natural gas, compressed or liquefied							1	373
Nitric acid (incl. fuming)	14	20,827	3	59	32	4,021	22	6270
Nitric acid (over 40%)	1	18					4	306
Nitric acid, fuming	1	2					3	1,143
Nitrogen	58	269,550	2	384	115	877,031	32	69,318
Non-flammable gas, n.o.s.	141	103,053	29	6,310	37	15,839	205	1,477,767
Organic peroxide, n.o.s.	2	2					2	11
Orm A, n.o.s.	2	7,874						
Orm B, n.o.s.					1	12,791		
Orm D, consumer commodity					1	54	10	4,619
Orm E, n.o.s.	5	11,544						
Other regulated material, liquid	3	79			4	6,373	1	626
Other regulated material, solid	1	159						
Oxidizer, n.o.s.	47	1,486	2	35	17	851	4	15,321
Oxygen	24	4,811	2	258	9	6,173	20	26,036
Poison, liquid, n.o.s.	47	5,880	4	124	11	756	1	1
Poison, solid, n.o.s.	50	258			5	393	1	1
Propane, compressed or liquefied	5	227			2	301	1	68
RAM, empty pkgs	68	313,080	88	159,735	12	4,474	17	24,540
RAM, fissile, <20% U-235	3	6,275						

Table G.2–3. Summary of Hazardous Materials Shipped To and From Department of Energy Sites–1994—Continued

	ORR		Pantex		RFETS		SRS	
Commodity	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)	Shipments (number)	Gross Weight (kg)
RAM, fissile, >20% U-235	15	2,318						
RAM, fissile, HRCQ								
RAM, fissile, HRCQ, IR PINS							17	212,305
RAM, fissile, HRCQ, UNIR PINS								
RAM, fissile, n.o.s.	10	36,770	1	1,659			2	220
RAM, fissile, UNIR PINS								
RAM, fissile, waste			1	7,254	1	7,971		
RAM, HRCQ, special	2	4,364						
RAM, instr. & articles	9	5,875	5	91				
RAM, LSA, n.o.s.	454	1,120,758	9	466	37	138,597		
RAM, LSA, UF_6	66	1,270,833						
RAM, LSA, waste	6	111,223			9	151,142		
RAM, ltd. quant., n.o.s.	209	197,911	48	57,469	18	4,201	239	64,891
RAM, medical isotopes	107	390						
RAM, n.o.s.	135	124,546	23	3,903	8	1,269	32	69,099
RAM, n.o.s., HRCQ	1	13,744						
RAM, n.o.s., special	58	38,376	6	89	1	4	6	216
RAM, n.o.s., waste	1	109						
RAM, U-metal, pyrop	3	529						
RAM, UO_x, n.o.s.	1	2						
Small arms ammunition	1	1,013	4	4,913	5	431		
Sodium hydroxide (caustic soda)	27	70,840			6	812	52	39,585
Sodium metal, (non-RAM)	3	65						
Sodium nitrate	3	233	1	2	3	331	3	169
Spontaneously combustible material	1	3			1	11		
Sulfuric acid	13	103,875			6	918	13	81,353

Table G.2–3. Summary of Hazardous Materials Shipped To and From Department of Energy Sites–1994—Continued

Commodity	ORR Shipments (number)	ORR Gross Weight (kg)	Pantex Shipments (number)	Pantex Gross Weight (kg)	RFETS Shipments (number)	RFETS Gross Weight (kg)	SRS Shipments (number)	SRS Gross Weight (kg)
Toxic gas, inhalation hazard	16	340	1	653	3	418	7	1,675
Trichloroethane 1,1,1	8	247	2	108				
Wet cell batteries	21	27,448	2	684	30	16,652	81	84,262
Total	3,169	6,438,750	612	328,331	671	3,389,442	1,152	2,754,435

Note: Gross weight (kg) includes the weight of the package; n.o.s.=not otherwise specified.
Source: SAIC 1995a:2.

Table G.3–1. Highway Distance Between Department of Energy Sites (kilometers)

Site	Hanford	NTS	INEL	Pantex	ORR	SRS	RFETS	LANL
Hanford	0	1,491	850	2,497	3,867	4,299	1,813	1,998
NTS	1,491	0	1,138	1,539	3,272	3,610	1,359	1,220
INEL	850	1,138	0	1,721	3,077	3,523	1,037	1,311
Pantex	2,497	1,539	1,721	0	1,732	2,070	726	535
ORR	3,867	3,272	3,077	1,732	0	531	2,145	2,267
SRS	4,299	3,610	3,523	2,070	531	0	2,590	2,605
RFETS	1,813	1,359	1,037	726	2,145	2,590	0	630
LANL	1,998	1,220	1,311	535	2,267	2,605	630	0

Source: DOE 1991j; DOE 1992o:3; McNally 1990a.

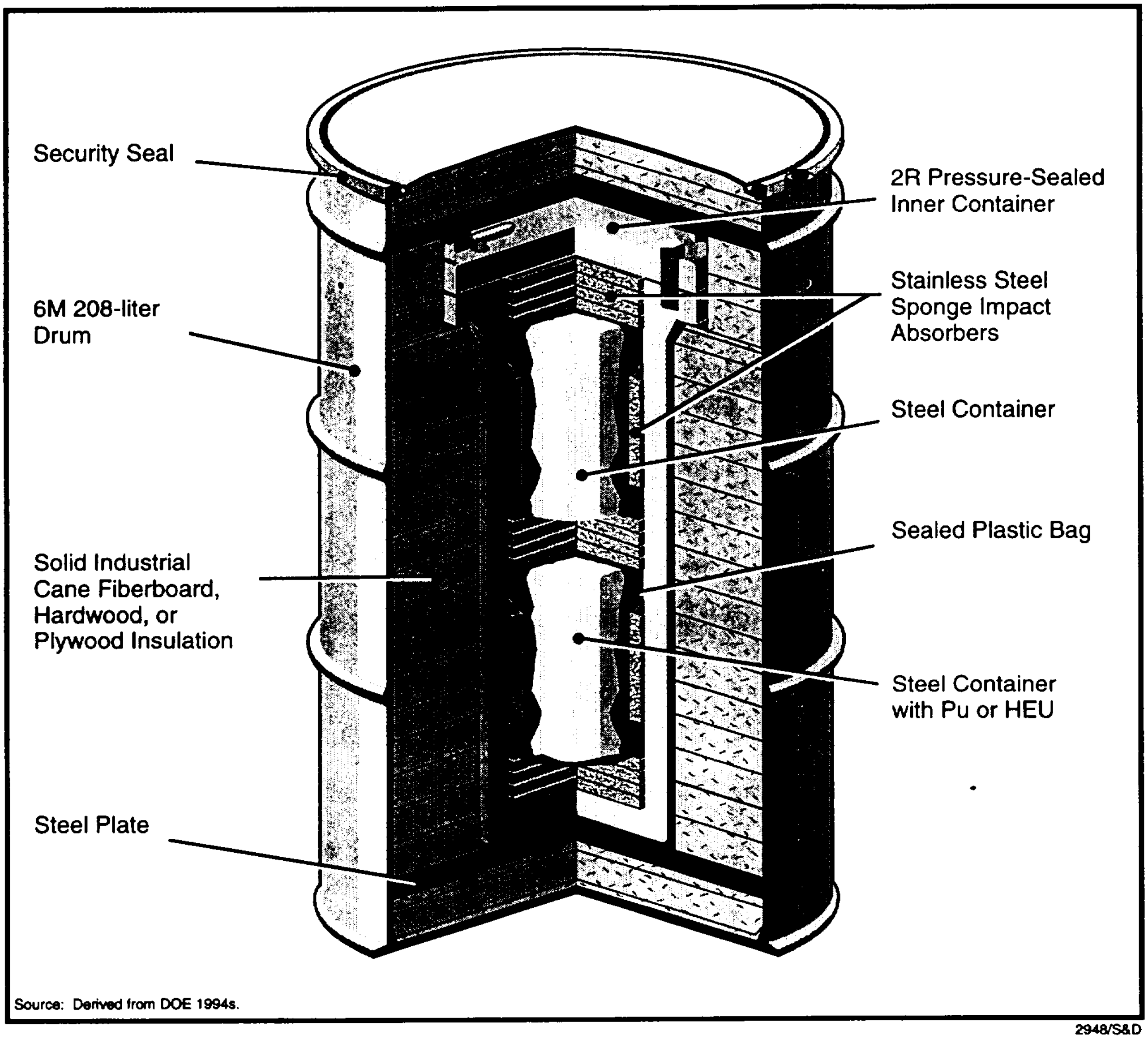
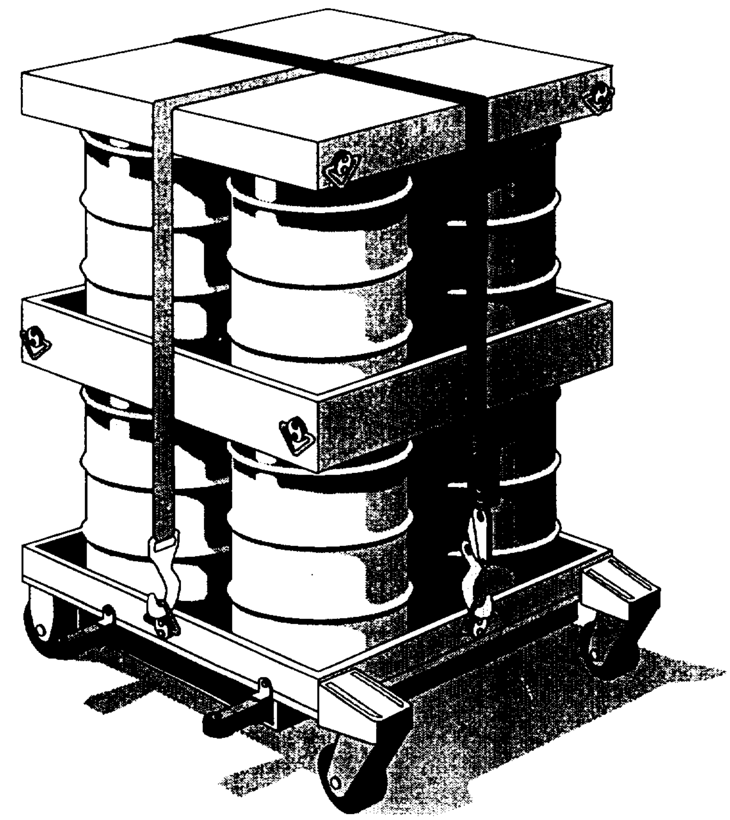


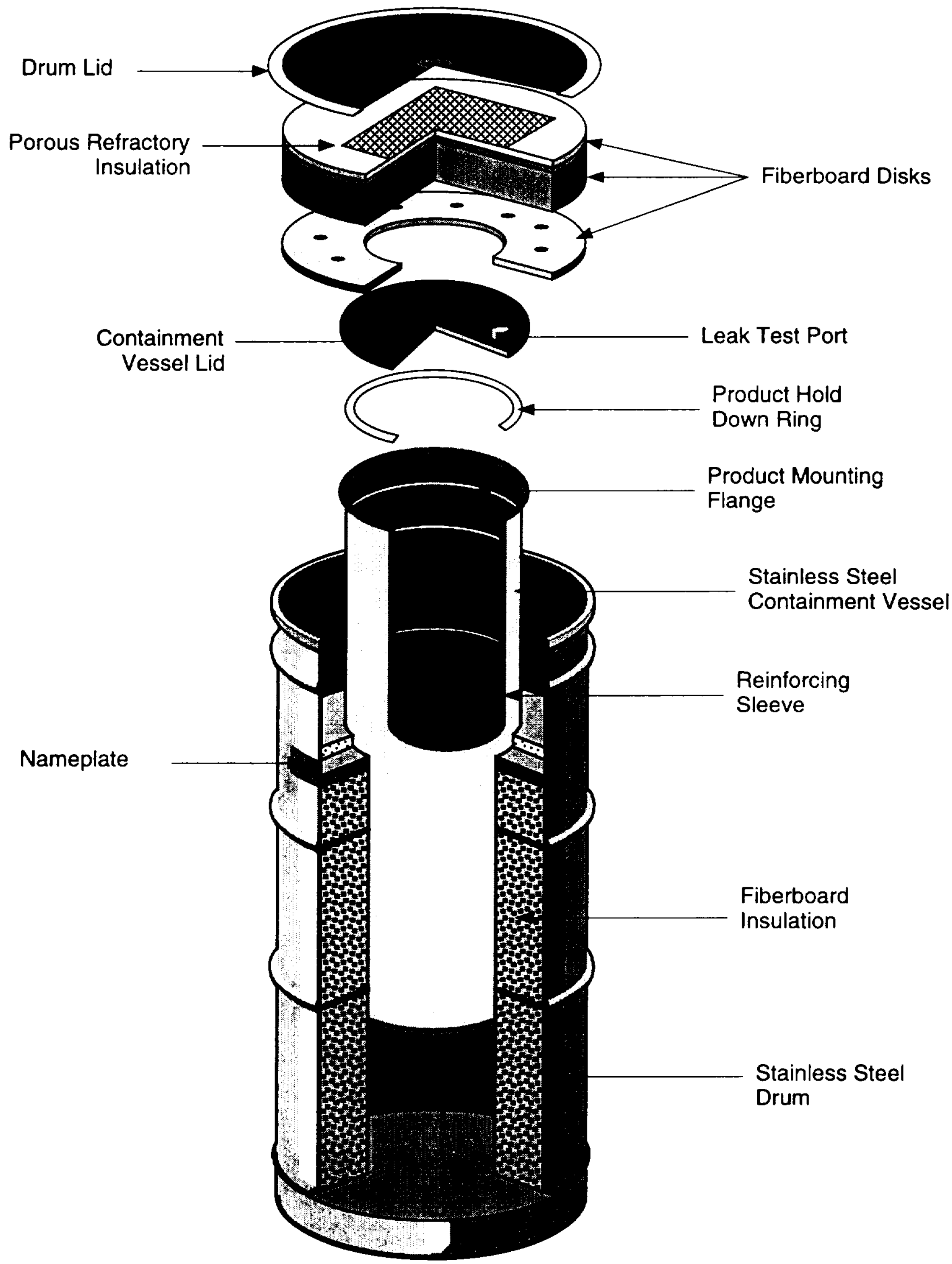
Figure G.4–1. Typical Assembly of 6M, Type B Packaging for Plutonium (Other Than Pits) or Highly Enriched Uranium



Source: Derived from SNL 1988b.

2949/S&D

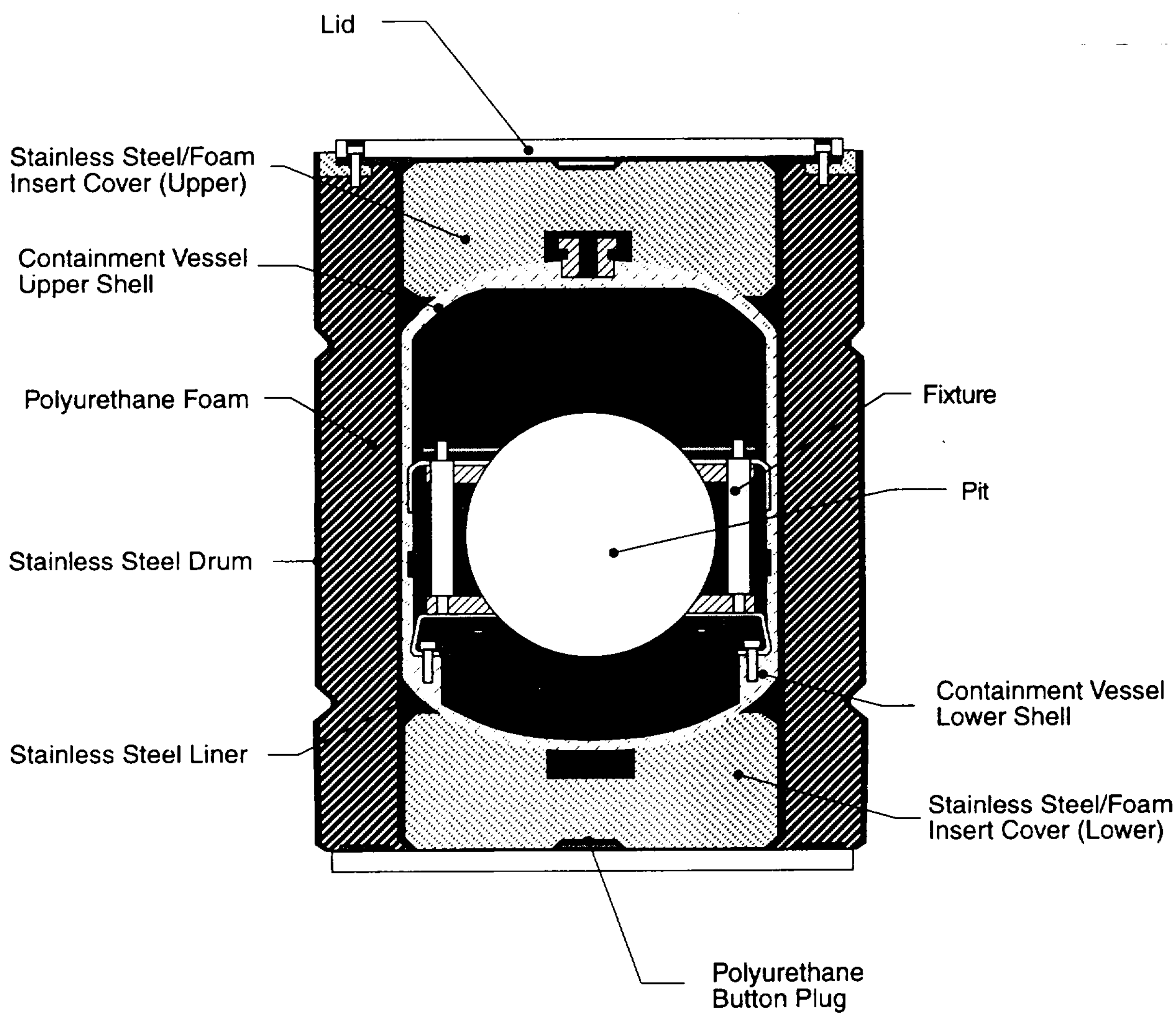
Figure G.4–2. Cargo Restraint Transporter Loaded With Drums.



Source: Derived from PX DOE 1996b.

2907/S&D

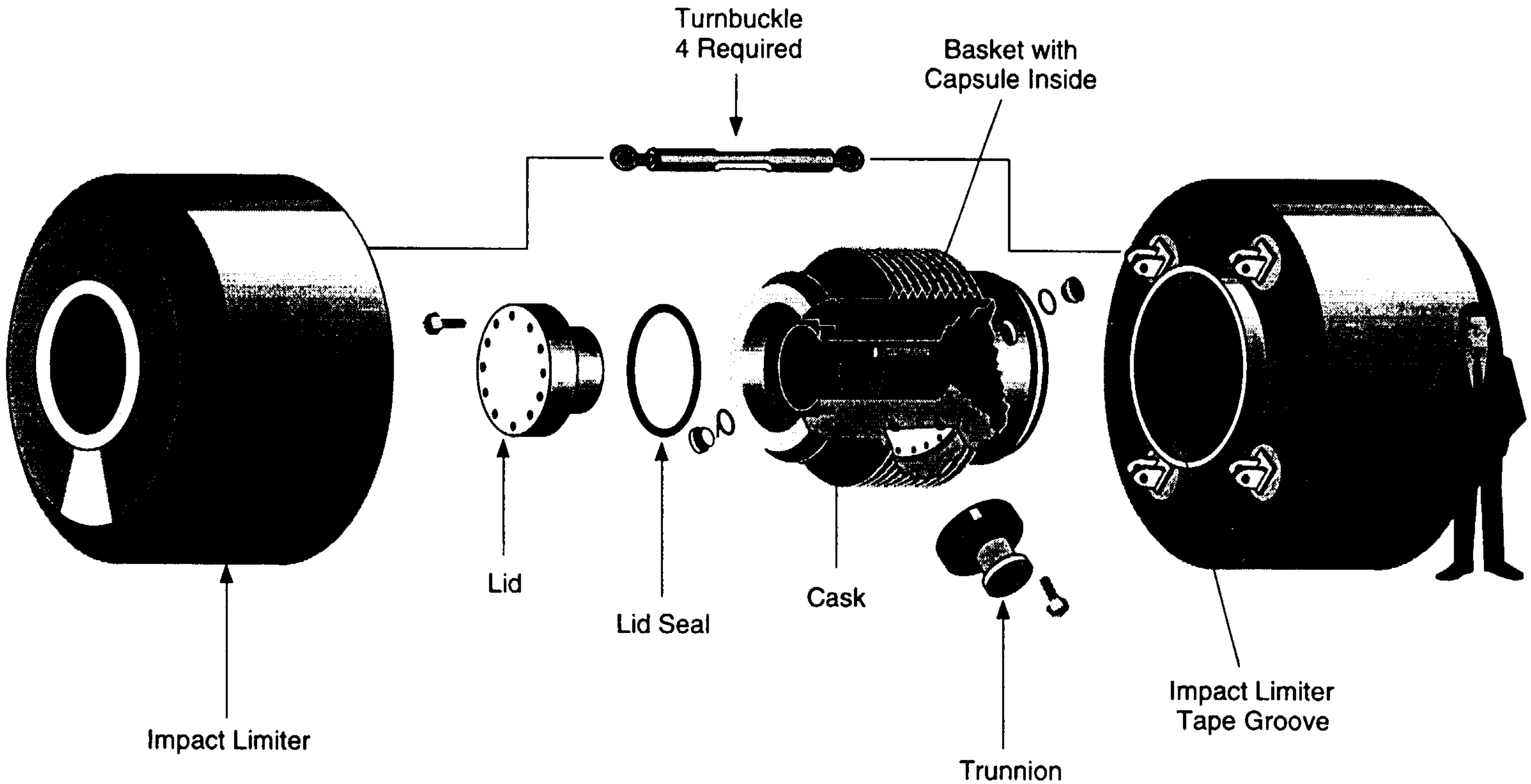
Figure G.4–3. Assembly of FL, Type B Packaging for the Transport of Plutonium Pits.



Note: Drawing not to scale.
Source: Derived from PX DOE 1996b.

3174/S&D

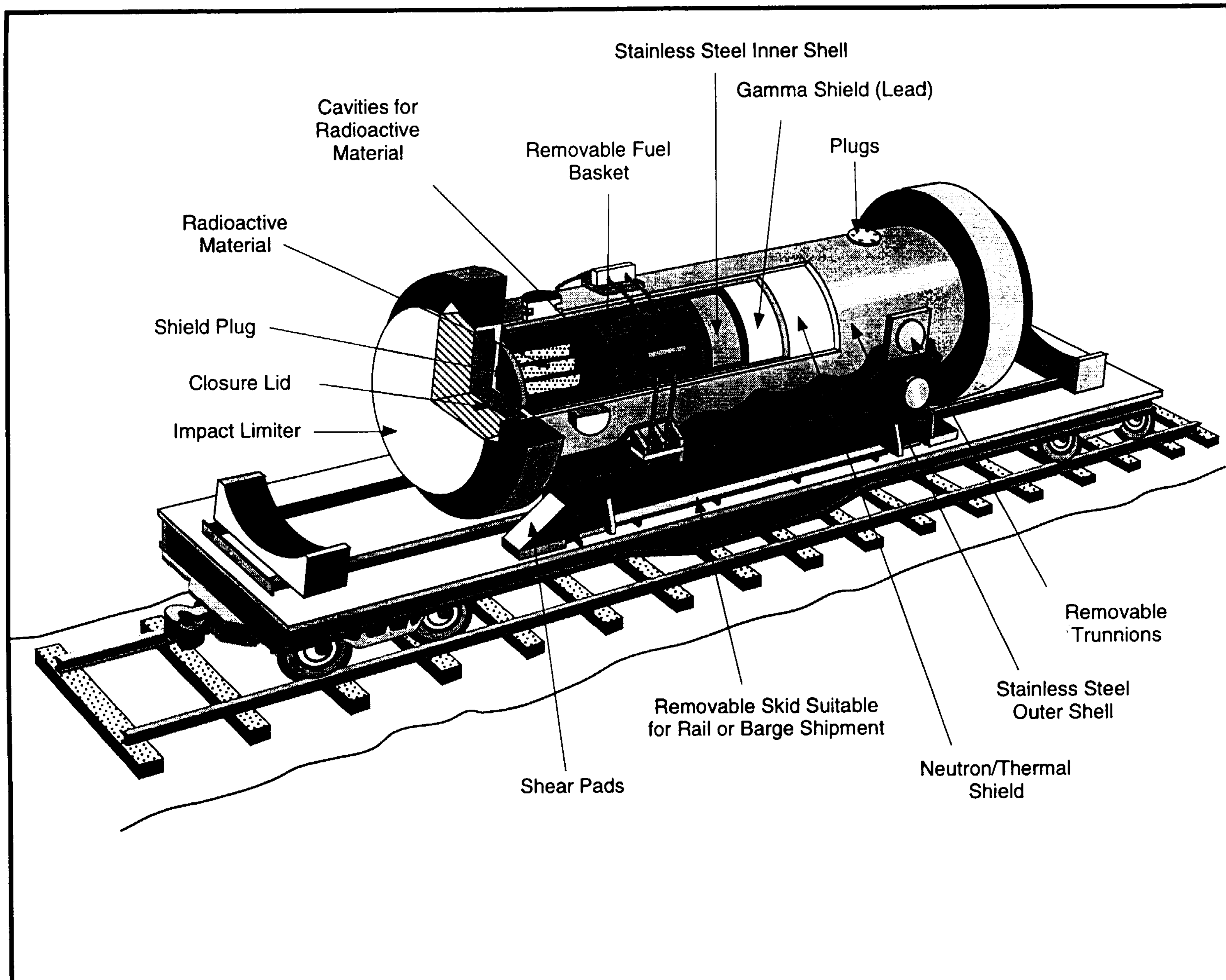
Figure G.4–4. AT-400A Packaging for the Transport of Plutonium Pits.



Source: Derived from DOE 1995bb.

2915/S&D

Figure G.4–5. Representation of the BUSS Cask for the Transport of Cesium Material.



Source: Derived from DOE 1991n.

2919/S&D

Figure G.4–6. Diagram of a Representative Spent Fuel Cask With Similar Characteristics to Be Employed for the Transport of Immobilized Plutonium.

G.5 6M, TYPE B RADIOACTIVE MATERIAL SHIPMENT PACKAGING TEST SEQUENCE

In addition to meeting DOT standards demonstrating it can withstand normal conditions of transport without loss or dispersal of its radioactive contents, the model 6M, Type B packaging used for DOE shipments must survive certain severe hypothetical accident conditions that demonstrate resistance to impact, puncture, fire, and water submersion. Test conditions do not duplicate accident environments, but rather, produce damage equivalent to extreme and unlikely accidents. The 6M, Type B packaging is judged as surviving extreme sequential testing if it retains all its contents except for minuscule allowable releases, and the dose rate outside the packaging does not exceed 1 rem/hr at a distance of 1 m (3.3 ft) from the package surface. Drum sizes (outer package) can vary from 38 to 416 liters (10 to 110 gallons).

The complete sequence of tests is listed below.

- **Drop Test.** A 9-m (30-ft) drop onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.

- **Puncture Test.** A 1-m (3.3-ft) drop onto the upper end of a 15-centimeter (6-inch) diameter solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface.

- **Thermal Test.** An exposure for no less than 30 minutes to a heat flux no less than that of a radiation environment of 800 °C (1,475 °F) with an emissivity coefficient of at least 0.9.

- **Water-Immersion Test.** A subjection to water pressure equivalent to immersion under a head of water of at least 15 m (50 ft) for no less than 8 hours.

The regulatory test conditions for the 6M, Type B packaging and other similar packaging are much more demanding than they might appear. For example, an impact on a very hard surface (desert caliche) at more than 322 km (200 mi) per hour is not as likely to deform the packaging as would a drop of 9 m (30 ft) onto an unyielding target.

A typical 6M, Type B packaging approved for use by DOE is covered by Certificate of Compliance Number 9859, dated January 5, 1994. The 6M, Type B packaging is made up of several components each with an integral engineered role in containment and confinement of the radioactive material being shipped. Although 6M, Type B packaging has been involved in severe accidents, the integrity of the packaging has never been compromised.

It is noted that there is some controversy concerning the adequacy of the Type B packaging. However, these packages are currently certified as safe for transporting radioactive materials. If the safety certification for the packaging is withdrawn, new analysis will be required.

G.6 SAFE SECURE TRANSPORT

Since 1947, DOE and its predecessor agencies have moved nuclear weapons, nuclear weapons components, and special nuclear materials by a variety of commercial and Government transportation modes. In the late 60s, worldwide terrorism and acts of violence prompted a review of procedures for safeguarding these materials. As a result, a comprehensive new series of regulations and equipment was developed to enhance the safety and security of these materials in transit. Subsequently, the Transportation Safeguards Division (TSD) was established in 1975 at the DOE Albuquerque Operations Office. TSD modified and redesigned transport equipment to incorporate features that more effectively enhance self protection and deny unauthorized access to the materials. During that time, TSD curtailed the use of commercial transportation systems and moved to a total Federal operation.

Management, control, and direction of TSD is centralized at Albuquerque Operation Office. Both the Federal officers who drive the transportation vehicles and the escorts are Nuclear Materials Couriers. There are three courier operations centers, located at Amarillo, Texas, Oak Ridge, Tennessee, and Albuquerque, New Mexico. Approximately 100 shippers and receivers of special nuclear material and other sensitive materials are served at locations throughout the continental United States.

Since its establishment in 1975, TSD has accumulated over 110 million km (70 million mi) of over-the-road experience transporting DOE-owned cargo with no accidents causing a fatality or release of radioactive material. This is due largely to the TSD philosophy that safety and security are of equal and paramount importance in the accomplishment of DOE's transportation safeguards mission.

The SST is a specially designed part of an 18-wheel rig that incorporates various deterrents to prevent unauthorized removal of cargo. The trailer has been designed to afford the cargo protection against damage in the event of an accident. This is accomplished through superior structural characteristics and a highly reliable cargo tiedown system similar to that used aboard aircraft. The thermal characteristics of the SST would allow the trailer to be totally engulfed in a fire without incurring damage to the cargo. The tractors are standard production units that have been modified to provide the couriers protection against attack. Other vehicles that make up the convoy may include Ford vans and Chevrolet Suburbans. These tractors and escort vehicles are equipped with communications, electronic, radiological monitoring, and other equipment that further enhance en route safety and security. The vehicles utilized by TSD must meet maintenance standards significantly more stringent than those for similar commercial transport equipment. All vehicles undergo an extensive maintenance check before every trip, as well as periodic preventative maintenance inspections. In addition, these vehicles are replaced more frequently than commercial shippers. As a result, TSD experiences few en route breakdowns and has had no accidents due to equipment malfunction.

The TSD makes every effort to ensure its convoys do not travel during periods of inclement weather. Should the convoys encounter adverse weather, provisions exist for the convoys to seek secure shelter at previously identified facilities. Although TSD provides sleeper berths in all vehicles, couriers accompanying TSD shipments do not exceed 32 hours of continuous travel without being afforded the opportunity for 8 hours of uninterrupted, stationary bed rest. TSD has also imposed a maximum 88-km/hr (55-mph) speed limit on its convoys, even if the posted limit is greater.

Security Communications is a nationwide communications system operated by TSD and located in Albuquerque. This system provides a capability to monitor the status and location of every convoy and maintain real-time communications 24 hours a day, 365 days a year with every convoy. The control center maintains an emergency contact directory of Federal, State, and local response organizations located throughout the contiguous United States. This capability is available to TSD 24 hours a day, 365 days a year.

Armed Nuclear Materials Couriers accompany each shipment containing special nuclear material. They also drive the highway tractors and escort vehicles while operating the communications and other convoy equipment. Couriers are non-uniformed Federal officers and are authorized by the *Atomic Energy Act* to make arrests and carry firearms in the performance of their duties. They carry both a photo identification card and shield which certify their Federal status. Couriers are required to obey all traffic laws and will cooperate fully with law enforcement officers. After careful screening and selection, courier trainees undergo a 12-week basic training course, during which they receive instruction in tractor-trailer driving, electronic and communications systems operation, and firearms. Tests in operating procedures, physical fitness, driving, firearms, and other job related subjects must be passed in order for a courier to be certified. Following basic training, the courier spends the balance of the first year in on-the-job training. The first year of employment is probationary, and the courier must successfully complete it to be retained. Couriers are given in-service training throughout their careers. These classes are designed to refresh and update the training taught during basic training, in addition to preparing couriers for demonstrations or armed attacks. Subjects such as team tactics, terrorist tactics, and new adversary

technology are taught. In addition, physical and firearm proficiency is tested. Couriers must continue to meet periodic qualification requirements relative to firearms, physical fitness, and driving proficiency. They must also undergo and pass an annual medical examination for continued certification under the DOE Personnel Assurance Program. In addition, couriers are subject to DOE's randomized drug and alcohol testing program. If a courier fails to meet any of the minimum requirements necessary for courier certification, the individual is temporarily removed from active status and provided additional training until demonstrated performance reaches an acceptable level.

The TSD has a liaison program through which it communicates with law enforcement and public safety agencies throughout the country, making them aware of these shipments. TSD has established procedures should an SST be stopped by an officer. The liaison program provides law enforcement officers information to assist them in recognizing one of these vehicles should it be involved in an accident, and what actions to take in conjunction with the actions of the couriers in the rig and the escort vehicles. Through the liaison program, TSD offers in-depth briefings at the State level (DOE 1993ff:1-4).

Appendix H
High-Level Waste Forms Comparative Analysis

H.1 METHODOLOGY

This appendix evaluates various plutonium (Pu) forms for potential disposal in a geologic repository. Although a repository site has not yet been recommended for development by the President and approved by Congress, this programmatic environmental impact statement (PEIS) assumes (for analysis purposes only) the existence of a hypothetical repository, managed by the Department of Energy (DOE) Office of Civilian Radioactive Waste Management, at the Yucca Mountain Site in southern Nevada. In accordance with the *Nuclear Waste Policy Act* (NWPA) of 1982, as amended by the NWPA Amendments of 1987 (42 USC 10101), DOE is evaluating the suitability of the Yucca Mountain Site as a potential geologic repository for the disposal of spent nuclear fuel and high-level waste (HLW). Such a repository, if approved under the provisions of the NWPA, would serve primarily as the disposal site for commercial and DOE-owned spent nuclear fuel and HLW. Certain highly radioactive material, which the Nuclear Regulatory Commission (NRC) determines by rule requires permanent isolation, may also be disposed of as HLW in a geologic repository. Such a NRC determination or legislative clarification may be required to dispose of the immobilized forms that would result from the Immobilization Alternatives. Since no waste forms are currently licensed for disposal in an HLW repository, data for forms under consideration in this PEIS for ultimate disposal in a repository are compared to data for those forms currently being evaluated for disposal in an NWPA-licensed repository (that is, commercial and DOE-owned spent nuclear fuel and vitrified HLW). The Environmental Protection Agency has specified that vitrification is the best demonstrated available technology for HLW (55 FR 22627). This approach implies that if the behavior of the Pu forms in a repository is the same or better than the commercial spent nuclear fuel or HLW, and if a repository can be licensed for commercial spent nuclear fuel and HLW, then it is possible that the proposed Pu forms could also be disposed in a repository. [Text deleted.] Due to the great amount of data and information available, U-based commercial spent nuclear fuel and vitrified HLW are used for the basis of the comparison.

If the DOE HLW Program changes its approach for disposal of commercial spent nuclear fuel, if the timeframe for acceptance of forms into the program is significantly delayed beyond Pu disposition requirements, or if the Pu immobilized forms or mixed oxide (MOX)-based spent nuclear fuel resulting from Pu disposition alternatives are determined to be unacceptable to a licensed repository, then DOE would analyze the impacts of continued storage of immobilized Pu or MOX-based spent nuclear fuel in a tiered *National Environmental Policy Act* of 1969 (NEPA) document. Simultaneously, DOE will continue its efforts to site and construct a repository that meets the requirements of the NWPA.

This appendix contains a comparative analysis of five Pu forms: (1) immobilized Pu and other radionuclides in borosilicate glass, (2) immobilized Pu and other radionuclides in ceramic disks, (3) boiling water reactor (BWR) MOX-based spent nuclear fuel, (4) pressurized water reactor (PWR) MOX-based spent nuclear fuel, and (5) immobilized Pu and other radionuclides in glass-bonded zeolite (GBZ). The purpose of this feasibility analysis is to compare the performance of these Pu forms against those currently being considered for disposal in a repository. The comparison for these Pu forms is based on information in the *Report on Evaluation of Plutonium Waste Forms For Repository Disposal*. Further, since the NWPA (as amended) identifies Yucca Mountain, Nevada, as the only location for repository site characterization studies, all candidate waste form performance analyses assume the same geological conditions (unsaturated tuff) as that site.

For each alternative, the total number of additional, if any, waste packages that would be added to the approximately 12,000 packages currently envisioned for the first HLW repository is small enough that any changes in emplacement could be accommodated within the design ratings of such a repository.

H.2 GLASS FORM WITH RADIONUCLIDES

The Pu-loaded glass form is assumed to be fabricated in a new facility using borosilicate glass as the vitrified matrix with the radioactive Cs isotope (Cesium-137) mixed in to provide a source of radiation as a barrier to theft and diversion. This PEIS analyzes only gadolinium (Gd) although boron and lithium neutron absorbers present in the borosilicate glass could be supplemented with samarium or other neutron absorbers.

H.2.1 ASSUMPTIONS

Figure H.2.1–1 shows the waste package containing the glass forms. For the purposes of the PEIS analyses, the following assumptions have been made:

- The waste is packaged as shown in Figure H.2.1–1.
- Molten glass is poured into stainless steel canisters to form encased glass logs that are similar to the Defense Waste Processing Facility (DWPF) glass logs and canisters.
- Each transportation cask holds five of these canisters; each disposal waste package holds four of these canisters.

H.2.2 CHARACTERISTICS

Each proposed glass log from a vitrification facility process consists of 1,540 kilograms (kg) (3,387 pounds [lb]) of borosilicate glass in a stainless steel canister containing 84 kg (185 lb) Pu, 1 kg (2.2 lb) Cs-137, and 55 kg (122 lb) Gd. The Gd, together with the boron and lithium in the glass, acts as a neutron absorber. Other than the addition of Pu, Cs, and Gd, the composition of this glass is assumed to be similar to the borosilicate glass candidate waste form in production at the DWPF at Savannah River Site.

H.2.3 COMPARATIVE ANALYSIS

Regulatory. Any waste form that is accepted for disposal in an HLW geologic repository must comply with the provisions of the NWPA, as amended. According to Section 2(12)A of the NWPA, the definition of HLW does not explicitly include Pu loaded into borosilicate glass. However, under Section 2(12)B of the NWPA, the NRC has the authority to classify this waste as HLW through rulemaking. Such rulemaking or clarification in authorizing legislation will be necessary before this waste form can be considered for disposal in an NWPA repository. The final disposal of this waste form will have to conform to the licensing provisions of 10 CFR 60. Further, it is current policy of the DOE not to accept into the first HLW repository any wastes that include components regulated as hazardous under the *Resource Conservation and Recovery Act* (RCRA) (DOE 1995a:6). The absence of any RCRA-regulated hazardous materials in the final glass form would have to be demonstrated prior to acceptance into the HLW repository.

Criticality. The effective neutron multiplication factor (k_{eff}) for the intact glass form, assuming credit for the neutron absorbers during the post-closure period, is calculated to be to less than 0.3, which is well below the 0.95 maximum value of k_{eff} allowed (10 CFR 60).

Thermal. As shown in Figure H.2.3–1, the results of a thermal analysis of a waste package containing four Pu glass logs indicate that the peak temperature reached by the glass package is about 200 degrees Centigrade (°C) (~400 degrees Fahrenheit [°F]), which is within 5 percent of the peak temperature predicted for the glass logs from the DWPF. These predicted temperatures are far lower than, and therefore safely away from, the glass transition temperature of 400 °C (750 °F). Such small differences in temperature and thermal output are unlikely to materially affect the thermal balance of any repository.

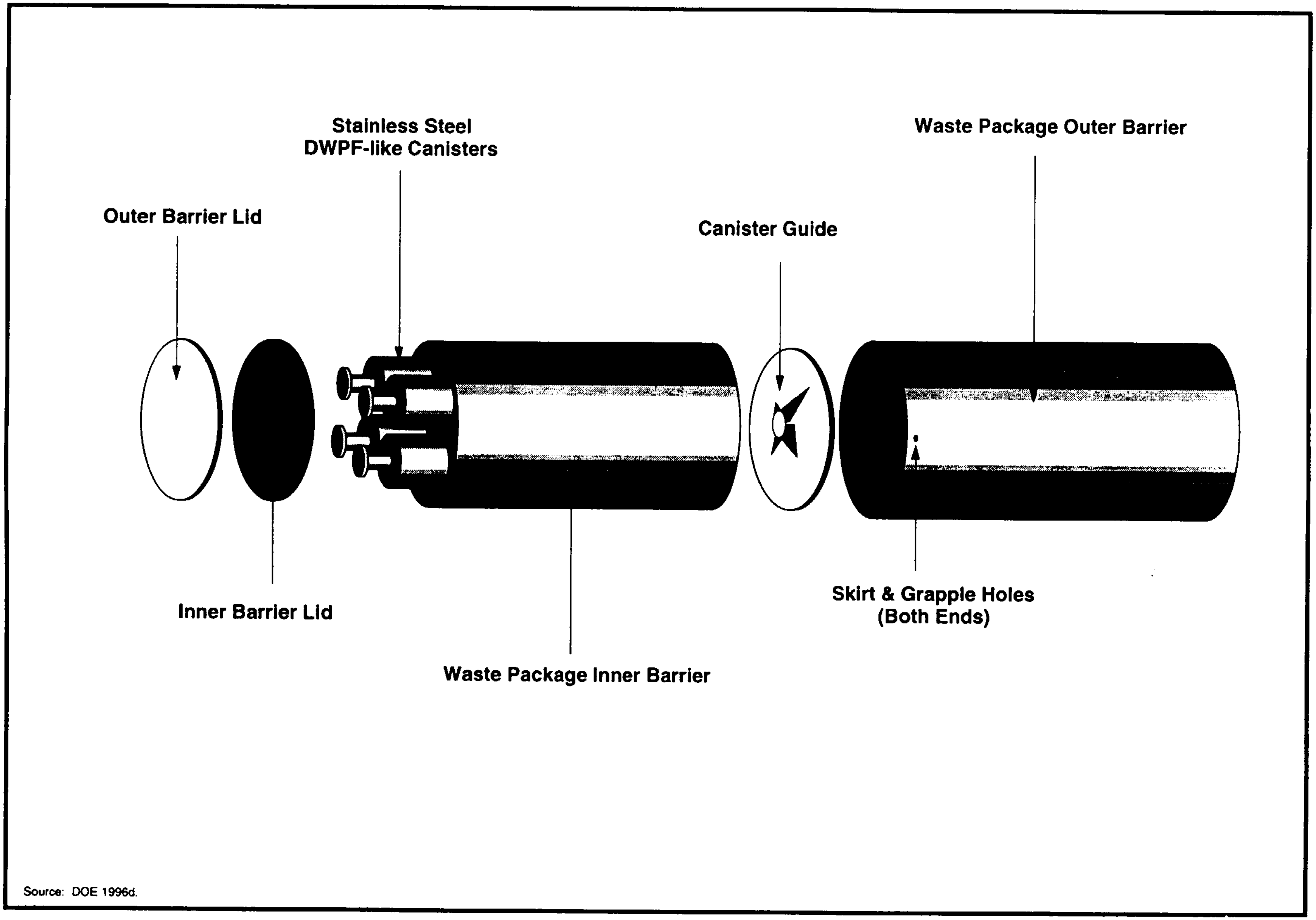


Figure H.2.1–1. Schematic of Waste Package Containing Canisters of Plutonium Immobilized in Glass.

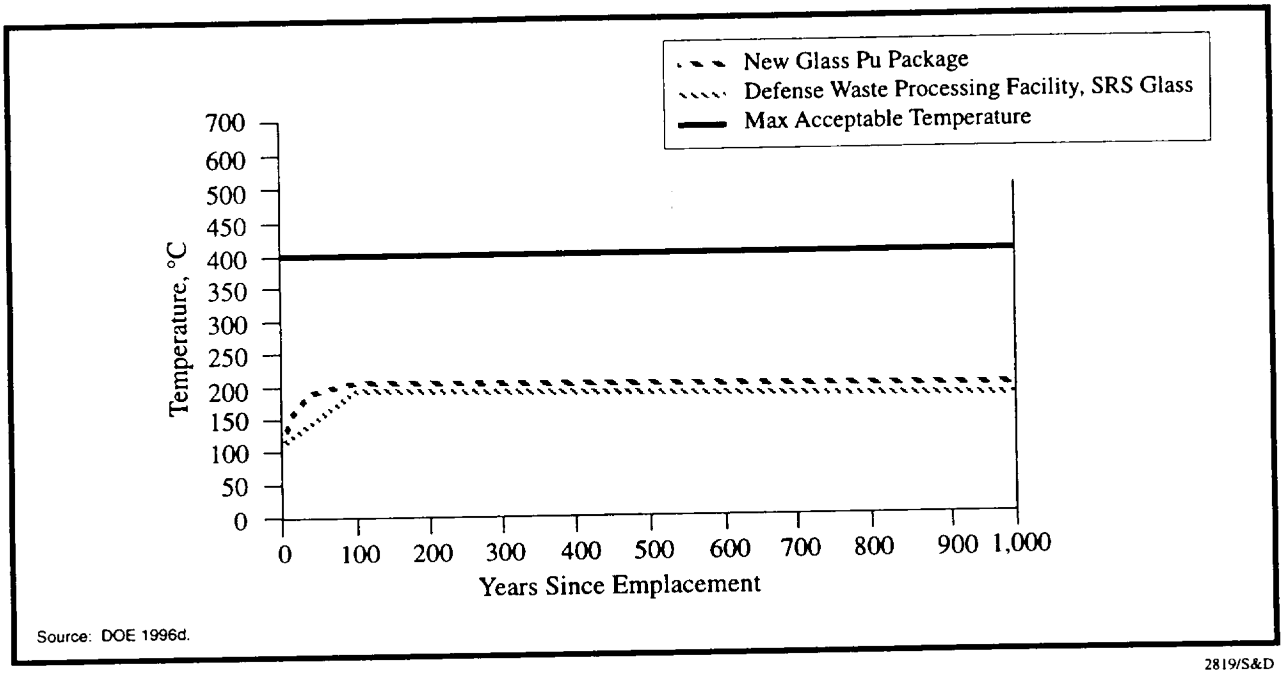


Figure H.2.3–1. Thermal Comparison of Plutonium-Loaded Glass Waste Package Versus Defense Waste Processing Facility Glass Waste Package.

Radiation. A comparison between the DWPF glass and the glass containing Pu shows that the radiation dose at the waste package surface is 81 roentgen equivalent man (rem)/hour (hr) for the DWPF glass compared to 129 rem/hr for the Pu glass. This Pu-glass radiation is above the threshold value for radiolytic corrosion. A 0.4 centimeters (cm) (0.16 inches [in]) additional thickness of the copper-nickel (Cu-Ni) alloy waste package outer barrier would be required to reduce the radiation to an acceptable (100 rad [radiation absorbed dose]/hr) level to protect the waste package from radiolysis-induced corrosion. Additional shielding is also required to protect workers. Doses at a distance of 2 meters (m) (6.6 feet [ft]) from the waste package surface show values of 12.5 rem/hr for the DWPF glass and 25 rem/hr for the Pu glass. For emplacement in the repository, only 5 cm (2 in) of lead thickness and 0.5 cm (0.2 in) of borated polyethylene neutron shielding must be added to the waste package underground transporter to reduce the radiation doses to meet the standard allowable dose of 10 millirem/hr at 2 m (7 ft) from lateral outer surfaces (49 CFR 173.441) to ensure worker protection. An alternative approach to accommodating the higher radiation from the Pu-loaded glass would be to reduce the number of canisters per waste package or the quantity of Cs-137.

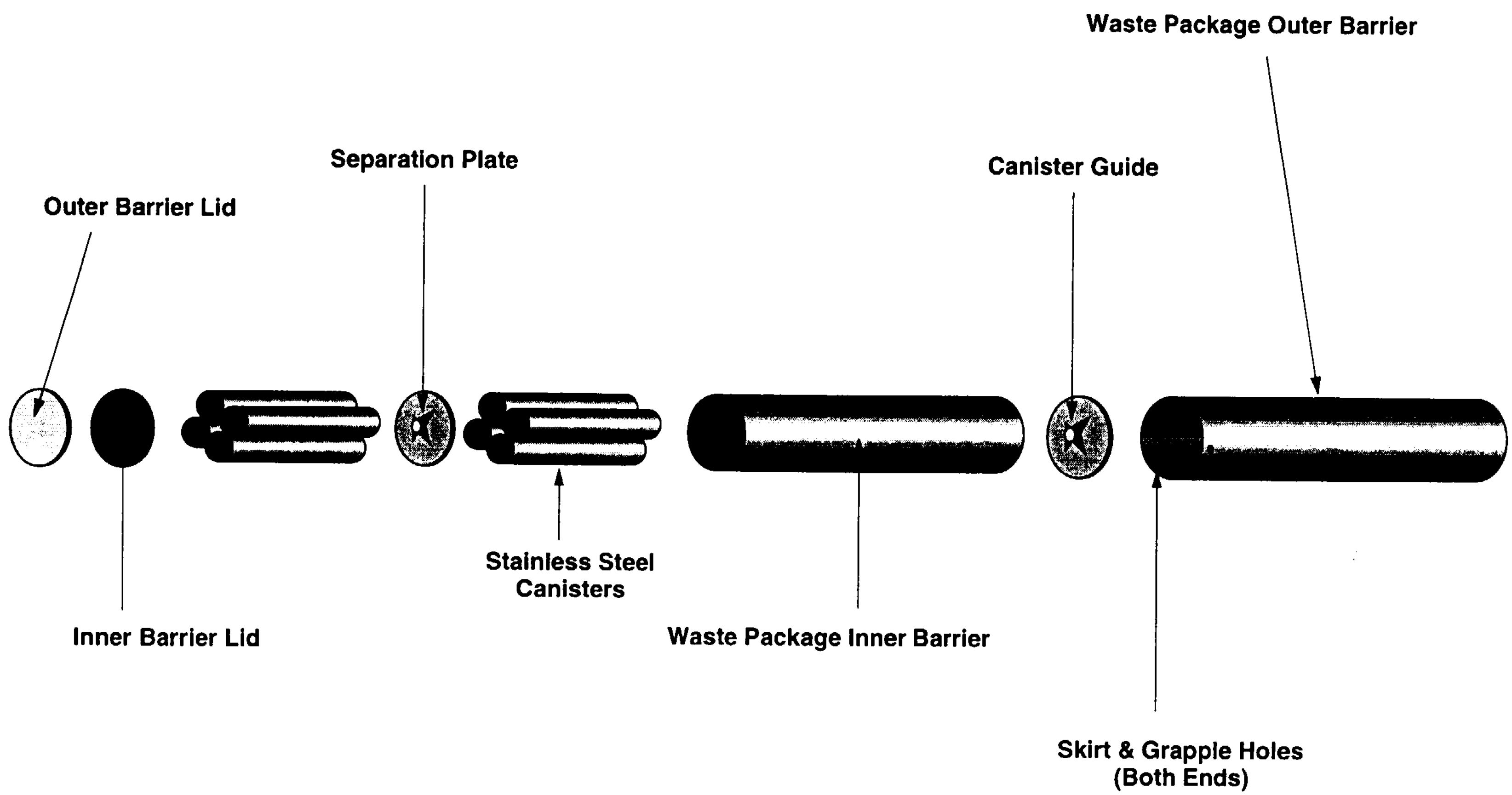
Releases. The peak doses from a repository that contains commercial spent nuclear fuel, vitrified HLW, and Pu immobilized in borosilicate glass are the same as from a repository that contains only commercial spent nuclear fuel and vitrified HLW, for periods up to one million years (DOE 1996d:4-12). These results are to be expected since the quantity of Pu glass is small compared to the quantity of spent nuclear fuel in the repository.

H.3 CERAMIC IMMOBILIZED FORMS WITH RADIONUCLIDES

The Pu-loaded ceramic matrix form is assumed to be fabricated in a new facility. As in the vitrification alternative, Cs-137 is mixed in to provide a source of radiation, and Gd acts as a neutron absorber.

H.3.1 ASSUMPTIONS

Figure H.3.1–1 shows the waste package containing the ceramic forms. For the purposes of the PEIS analyses, the following assumptions have been made:



Source: DOE 1996d.

3037/S&D

Figure H.3.1–1. Schematic of Waste Package Containing Canisters of Plutonium Immobilized in Ceramic.

- The waste is packaged as shown in Figure H.3.1–1.
- Ceramic disks will be stacked inside stainless steel canisters. These canisters are similar to the DWPF canisters.
- Each disposal waste package holds eight of these canisters.

H.3.2 CHARACTERISTICS

Each canister of the proposed waste form contains 20 ceramic disks; each disk is approximately 30 cm (12 in) in diameter, and 10 cm (4 in) thick. Each disk has stainless steel plates added to the top and bottom, and a stainless steel shell around the curved surface. The disks are stacked vertically in a stainless steel canister approximately 2.5 m (8 ft) long, and 35 cm (14 in) in diameter. The ceramic disks consist of zirconolite, hollandite, and rutile. For each disk, the zirconolite incorporates 2.6 kg (6.0 lb) of Gd, and the hollandite incorporates 4.0 kg (9.0 lb) of Pu and 0.07 kg (2.0 oz) of Cs-137. The space surrounding the stack of disks inside the canister is filled with titanium oxide powder.

H.3.3 COMPARATIVE ANALYSIS

Regulatory. Any waste form that is accepted for disposal in an HLW geologic repository must comply with the provisions of the NWPA, as amended. According to Section 2(12)A of the NWPA, the definition of HLW does not explicitly include Pu loaded into a ceramic matrix. However, under Section 2(12)B of the NWPA, the NRC has the authority to classify this waste as HLW through rulemaking. Such rulemaking or clarification in authorizing legislation would be necessary before this waste form can be considered for disposal in an NWPA repository. The final disposal of this waste form will have to conform to the licensing provisions of 10 *Code of Federal Regulations* (CFR) 60. Further, it is current policy of the DOE not to accept into the first HLW repository any wastes which include components regulated as hazardous under RCRA (DOE 1995a:6). The absence of any RCRA-regulated hazardous materials in the final ceramic form would have to be demonstrated prior to acceptance into the HLW repository.

Criticality. Preliminary criticality calculations for the intact ceramic waste package, under dry or flooded conditions, and assuming credit for the Gd neutron absorber, yields k_{eff} values of less than 0.7, which is below the 0.95 maximum value of k_{eff} allowed (10 CFR 60).

Thermal. As shown in Figure H.3.3–1, the results of a thermal analysis of Pu-loaded ceramic waste packages shows that peak temperatures are around 200 °C (~400 °F), declining as a function of time. Ceramic, unlike glass, does not have a transition temperature because it is a crystalline material. The lowest melting point temperature for the oxides of this ceramic material is around 1800 °C (3270 °F). Therefore, the calculated peak temperatures are unlikely to affect the ceramic matrix. Further, the temperature differences between the ceramic waste package and the DWPF HLW glass waste package are negligibly small.

Radiation. A comparison between the DWPF HLW glass and the Pu-loaded ceramic shows that the radiation dose at the waste package surface is 81 rem/hr for the DWPF glass compared to 309 rem/hr for the ceramic. The radiation level for the ceramic form is above the threshold value for radiolytic corrosion. Consequently, a 1-cm (0.4-in) additional thickness of the Cu-Ni alloy waste package outer barrier would be required to reduce the radiation to an acceptable level (100 rad/hr) to protect the waste package from radiolytic corrosion. Additional shielding is also required to protect workers. Doses at 2 m (6.6 ft) from the package surface show values of 12.5 rem/hr for the DWPF glass and 56.4 rem/hr for the ceramic. For emplacement in a repository, only 5 cm (2 in) of lead thickness and 0.5 cm (0.2 in) of borated polyethylene neutron shielding must be added to the waste package underground transporter to reduce the radiation doses to meet the standard allowable dose of 10 mrem/hr at 2 m (7 ft) from lateral surfaces (49 CFR 173.441) to ensure worker protection. An alternative approach to

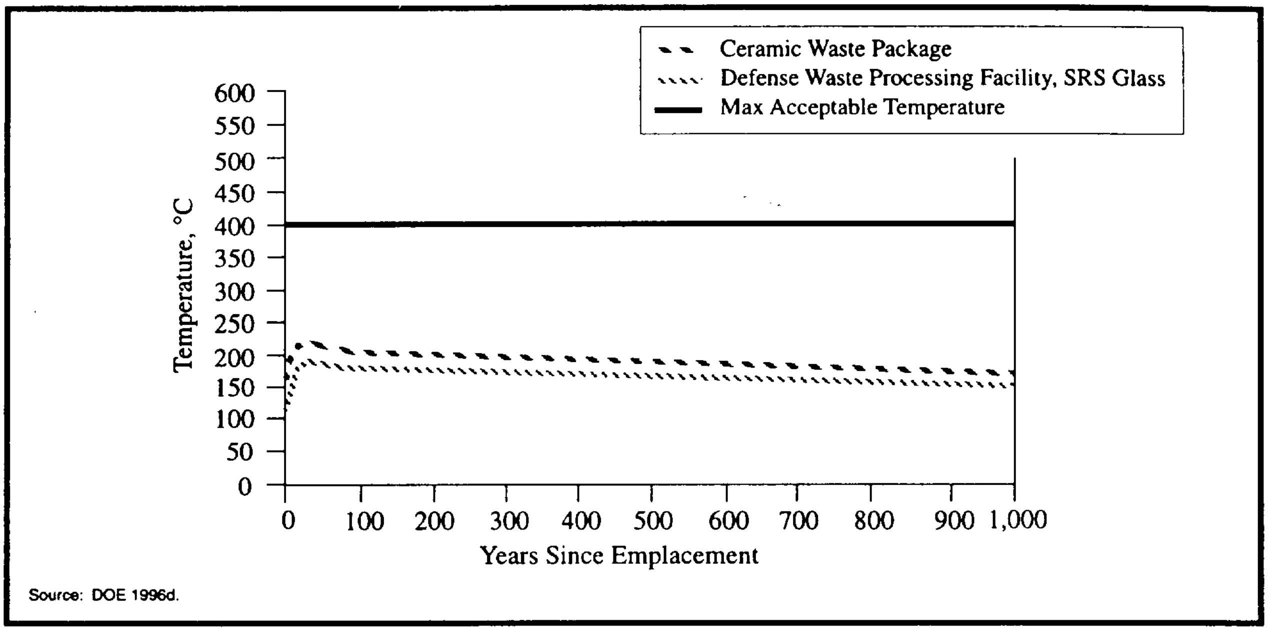


Figure H.3.3–1. Thermal Comparison of Plutonium-Loaded Ceramic Waste Package Versus Defense Waste Processing Facility Glass Waste Package.

accommodating the higher radiation fields from the Pu-loaded ceramic would be to reduce either the number of canisters per package or the quantity of Cs-137.

Releases. The peak doses from a repository that contains commercial spent nuclear fuel, vitrified HLW, and Pu immobilized in ceramic are the same as from a repository that contains only commercial spent nuclear fuel and vitrified HLW, for periods up to one million years. The difference in dose rates is insignificant between these two cases (DOE 1996d:5-12). These results are to be expected since the quantity of Pu in ceramic is small compared to the quantity of spent nuclear fuel in the repository.

H.4 BOILING WATER REACTOR—MIXED OXIDE BURNING REACTOR SPENT NUCLEAR FUEL FORM

Boiling water reactors are used in existing commercial power generation; therefore, the BWR form of the MOX spent nuclear fuel could be the output product from both the Existing LWR Alternative and the Partially Completed LWR Alternative if the latter is consistent with the BWR design. The performance of this MOX spent fuel is compared to the corresponding commercial BWR uranium-based boiling water reactors spent nuclear fuel.

H.4.1 ASSUMPTIONS

For the purposes of the PEIS analyses, the following assumptions have been made:

- The Pu will be fabricated into MOX nuclear reactor fuel and used for power generation in four boiling water reactors and allowed to cool at the reactor site(s) in the spent fuel pools for at least 10 years before shipment to a repository.

- The spent fuel will be emplaced in large (40 BWR assembly) waste packages for emplacement in a repository.

H.4.2 CHARACTERISTICS

The MOX spent fuel assembly from existing BWRs will have the following characteristics: (1) total Pu of 3.4 kg (7.5 lb), (2) Pu-239 to total Pu ratio of 0.4, (3) total heavy metal content of 172 kg (379 lbs), and (4) burn up of 37.6 gigawatt-days (GWd)/ton (t) of heavy metal. Radiation is analyzed using neutron and gamma source strengths by energy group.

H.4.3 COMPARATIVE ANALYSIS

Regulatory. An HLW repository, if approved under the provisions of the NWPA, would serve primarily as the disposal site for commercial spent nuclear fuel and defense-generated HLW. The MOX spent fuel that would be generated by this alternative falls within the definition of "spent nuclear fuel" per Section 2(23) of the NWPA and could, therefore, be considered a candidate for disposal in an NWPA repository. Licensing for the disposal of this MOX spent fuel form must follow the provisions of 10 CFR 60.

Criticality. Figure H.4.3–1 compares the results of the criticality analyses for a waste package containing all MOX spent fuel with one containing U-based spent fuel. The k_{eff} for the MOX spent fuel is below that of U-based fuels and well below the 0.95 maximum value allowed for k_{eff} (10 CFR 60).

Thermal. Figure H.4.3–2 shows the results of a thermal analysis of the MOX spent fuel element in a fully loaded, emplaced waste package. The peak cladding temperature is below the 350 °C (662 °F) limit required to maintain cladding integrity. Calculations also indicate that for the first 100 years the MOX cladding temperature continues to be lower than that of the corresponding U-based spent fuel. The slightly higher temperatures beyond the 100 years are so small as to have a negligible affect on the thermal balance of any repository.

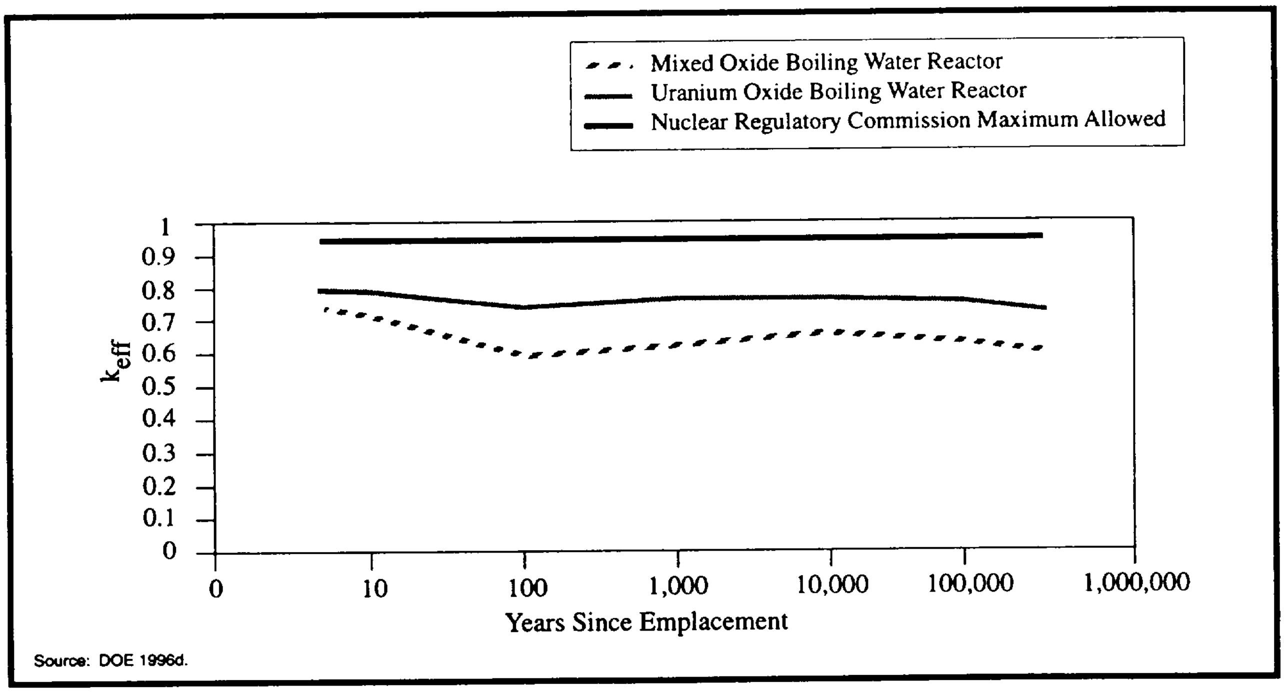


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Figure H.4.3–1. Effective Multiplication Factor (k_{eff}) of a Boiling Water Reactor Spent Fuel Waste Package.

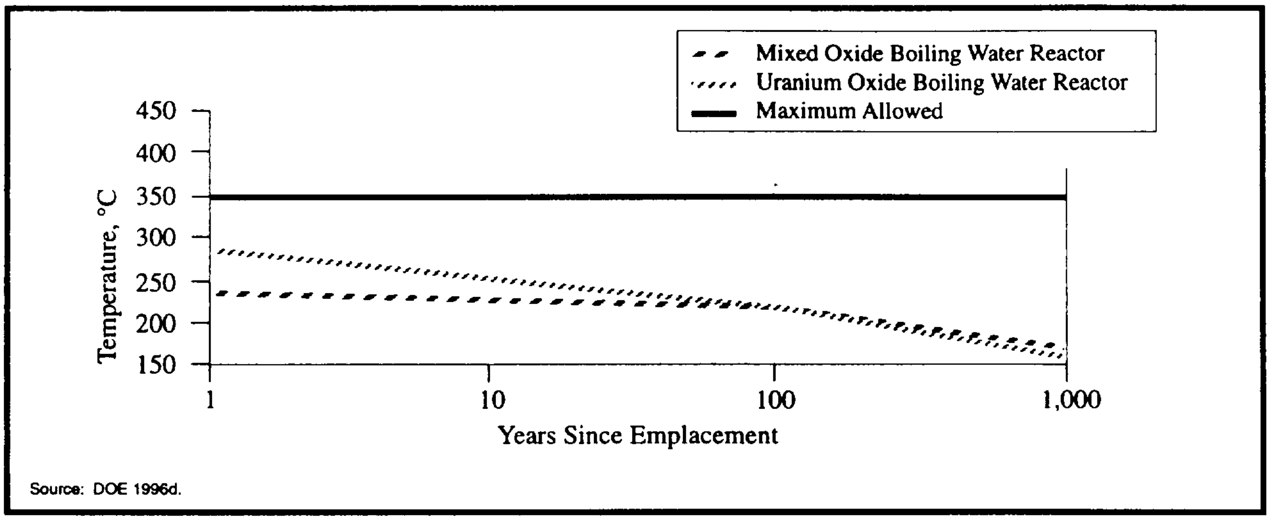

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Figure H.4.3–2. Thermal Comparison of Peak Cladding Temperature of Boiling Water Reactor Fuel Element Versus Uranium-Based Reactor Fuel Element.

Radiation. Radiation calculations predict that the unshielded dose rates at a distance of 2 m (6.6 ft) are slightly higher for the waste packages containing MOX fuel than for those containing uranium-based fuels. The gamma radiation dose for the MOX fuel is 5 rem/hr versus 4 rem/hr for the U-based fuel. The neutron radiation dose is 1.54 rem/hr for the MOX as versus to 0.8 rem/hr for the uranium fuel. The higher radiation doses can be accommodated by increasing the transporter shielding thickness by 0.125 cm (0.05 in) of lead for the gamma radiation, and 1.25 cm (0.5 in) of boron-polyethylene for the neutron radiation.

Releases. The calculated doses for just the waste packages of MOX-based spent fuel are 100 times less than that for a repository that contains both MOX and (U-based) commercial spent nuclear fuels (DOE 1996d:3-8). These results support the conclusion that the performance of the repository is dominated by the presence of (U-based) commercial spent nuclear fuel and is expected since the quantity MOX-based spent nuclear fuel is small compared to the larger quantity of commercial spent nuclear fuel in the repository.

H.5 PRESSURIZED WATER REACTOR—MIXED OXIDE BURNING REACTOR SPENT NUCLEAR FUEL FORM

For the Evolutionary LWR Alternative, a PWR could be the design for burning MOX fuel. PWRs are used in existing commercial power plants; therefore, the PWR form of the spent MOX nuclear fuel could be the output product from the Evolutionary LWR Alternative, Existing LWR Alternative, and the Partially Completed LWR Alternative if the latter reactors are consistent with the PWR design. The performance of this MOX spent nuclear fuel is compared to the corresponding U-based PWR spent nuclear fuel.

H.5.1 ASSUMPTIONS

For the purposes of the PEIS analyses, the following assumptions have been made:

- The Pu will be fabricated into MOX nuclear fuel and used for power generation in two PWRs and allowed to cool at the reactor site(s) in the spent fuel pools for at least 10 years before shipment to a repository.
- The spent fuel will be emplaced in large waste packages for emplacement in a repository.

H.5.2 CHARACTERISTICS

The MOX spent fuel assembly from an evolutionary PWR will have the following characteristics: (1) total Pu of 20 kg (44 lb), (2) Pu-239 to total Pu ratio of 0.6, (3) total heavy metal content of 410 kg (900 lbs), and (4) burn up of 43 GWd/t of heavy metal. Radiation is analyzed using neutron and gamma source strengths by energy group.

H.5.3 COMPARATIVE ANALYSIS

Regulatory. An HLW repository, if approved under the provisions of the NWPA, would serve primarily as the disposal site for commercial and DOE-owned spent nuclear fuel and HLW. The MOX spent fuel that would be generated by this alternative falls within the definition of "spent nuclear fuel" per Section 2(23) of the NWPA and could, therefore, be considered a candidate for disposal in an NWPA repository. Licensing for the disposal of this MOX spent fuel form must follow the provisions of 10 CFR 60.

Criticality. Calculations for a MOX PWR spent fuel waste package show that to maintain a value below the 0.95 maximum value allowed for k_{eff} (10 CFR 60), the waste package can hold only four assemblies. This calculation assumed no additional criticality control technology. Should such technology be applied (for example, disposable control rod assemblies were added to the waste packages) calculations show that 21 assemblies could be loaded in each waste package. For either the 4 or 21 assemblies/waste package case, the k_{eff} value is expected to decline with time in a manner similar to that of the BWR spent fuel waste package as shown in Figure H.4.3–1.

Thermal. Figure H.5.3–1 shows the results of a thermal analysis of the MOX PWR spent fuel. The peak cladding temperature is below the 350 °C (662 °F) limit required to maintain cladding integrity. For the first 100 years the temperature also remains lower than that of the corresponding U-based spent fuel. The additional heat from all the spent nuclear fuel packages produced by the PWRs would be so small as to have a negligible affect on the thermal balance of any repository.

Radiation. Radiation calculations for the 21-assembly MOX PWR waste package shows that the higher dose rates from the MOX package (compared to the package containing U-based spent fuel) can be easily accommodated by increasing the transporter shielding thickness by 0.4 cm (0.16 in) of lead for the gamma radiation, and 1.25 cm (0.5 in) of boron-polyethylene for the neutron radiation. The shielding thickness requirements for a four-assembly package will be less than these values.

Releases. The calculated doses for just the waste packages of MOX-based spent fuel are 100 times less than that for a repository that contains both MOX and (U-based) commercial spent nuclear fuel (DOE 1996d:6-7). These results support the conclusion that the performance of the repository is dominated by the presence of (U-based) commercial spent nuclear fuel and is expected since the quantity of MOX-based spent fuel is small compared to the larger quantity of commercial spent fuel in the repository.

H.6 GLASS-BONDED ZEOLITE FORM

The Pu-loaded GBZ form is assumed to be fabricated in an electrometallurgical treatment process and has characteristics for long term disposability in a repository that are similar to the borosilicate glass produced in the DWPF (DOE 1996d:4-1). The GBZ waste form constitutes another immobilization alternative which would require disposal in a repository.

H.6.1 ASSUMPTIONS

For the purposes of the PEIS analyses, the following assumptions have been made:

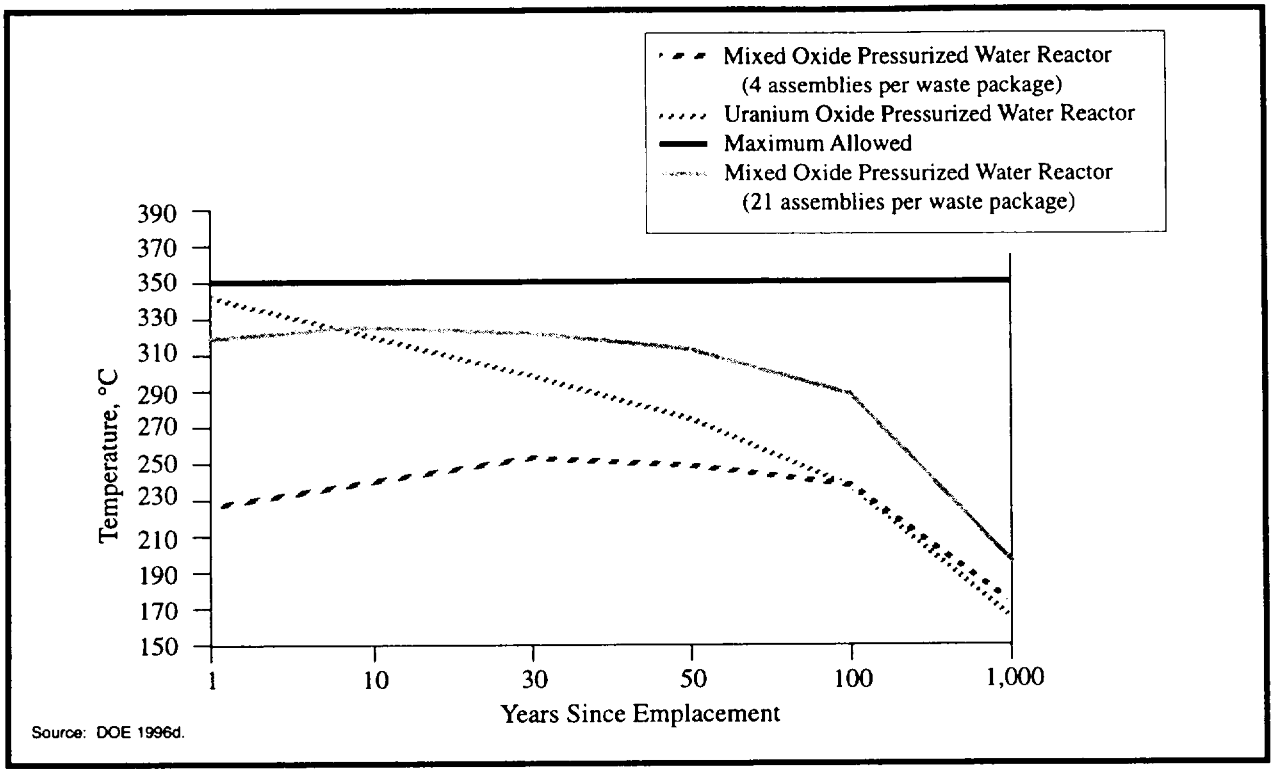


Figure H.5.3–1. ***Thermal Comparison of Peak Cladding Temperature of Pressurized Water Reactor Fuel Element Versus Uranium-Based Reactor Fuel Element.***

- The waste form is packaged in DWPF-like canisters.
- Each transportation cask holds five of these canisters; each disposal waste package holds four of these canisters.

H.6.2 CHARACTERISTICS

The GBZ will be prepared by sorbing a molten chloride Pu salt on an anhydrous zeolite, which is then blended with a glass frit. The whole mixture is heated in a mold to above the glass transition temperature and pressed to bond the zeolite to the glass. The chemical constituents of the waste form are as follows: 52 kg (114 lbs) of Pu, 21 kg (46 lbs) of Gd, 5 kg (11 lbs) of Cs, 364 kg (800 lbs) of zeolite, and 520 kg (1,144 lbs) of borosilicate glass. The remainder is made up of barium, lithium, potassium, sodium, and chlorides.

H.6.3 COMPARATIVE ANALYSIS

Regulatory. Any waste form that is accepted for disposal in an HLW geologic repository must comply with the provisions of the NWPA, as amended. According to Section 2(12)A of the NWPA, the definition of HLW does not explicitly include Pu loaded into GBZ. However, under Section 2(12)B of the NWPA, the NRC has the authority to classify this waste as HLW through rulemaking. Such rulemaking or clarification in authorizing legislation will be necessary before this waste form can be considered for disposal in an NWPA repository. The final disposal of this waste form will have to conform to the licensing provisions of 10 CFR 60. Further, it is current policy of the DOE not to accept into the first HLW repository any wastes that include components regulated as hazardous under RCRA (DOE 1995a:6). The absence of any RCRA-regulated hazardous materials in the final GBZ form would have to be demonstrated prior to acceptance into the HLW repository.

Criticality. Preliminary criticality calculations show the Pu-loaded GBZ in a dry, intact configuration has a k_{eff} of less than 0.2, which is less than the borosilicate glass form primarily because of the lower total Pu content of each waste package containing the GBZ. The k_{eff} values for the GBZ under flooded conditions are less than half the 0.3 value (0.13) calculated for the borosilicate glass form and well below the 0.95 maximum value allowed for k_{eff} (10 CFR 60).

Thermal. Because the Pu concentration in a waste package containing Pu-loaded GBZ canisters is 80 percent of the Pu concentration in a package containing Pu-loaded borosilicate glass, and because the peak temperature reached by borosilicate glass is below the 400 °C (750 °F) glass transition value, the peak temperature for the GBZ is also expected to be below the 400 °C (750 °F) glass transition temperature. More specifically, the lower Pu content of the GBZ means that the heat generation at 40 years and beyond would be much smaller than for the Pu-loaded borosilicate glass.

Radiation. A comparison between the DWPF HLW glass and the Pu-loaded GBZ shows that the radiation dose at the waste package surface is 81 rem/hr for the DWPF glass compared to 120 rem/hr for the Pu-loaded GBZ. Since the radiation level for GBZ is above the threshold value of 100 rads/hr for radiolytic corrosion, the waste package outer barrier thickness would need to be increased by 0.3 cm (0.11 in). Additional shielding is also required to protect workers. The dose rate at 2 m (6.6 ft) from the waste package is 23 rem/hr for the GBZ versus 12.5 rem/hr for DWPF glass. As in the case for the Pu-loaded borosilicate glass form, the addition of 5 cm (2 in) of lead shielding to the underground transporter would reduce the radiation doses to meet the standard allowable dose of 10 mrem/hr at 2 m (6.6 ft) from lateral outer surfaces (49 CFR 173.441) to ensure worker protection.

Releases. The peak doses from a repository that contains commercial spent nuclear fuel, vitrified HLW, and Pu immobilized in GBZ are the same as from a repository that contains only commercial spent nuclear fuel and vitrified HLW, for periods up to 1 million years (DOE 1996d:7-9). These results are to be expected since the quantity of Pu in GBZ is small compared to the quantity of spent nuclear fuel in the repository.

Appendix I
Changes in Canadian Deuterium Uranium Reactor Operations

Ontario Hydro operates 20 Canadian Deuterium Uranium (CANDU) reactors capable of using mixed oxide (MOX) at five nuclear generating stations in the Province of Ontario. Eight of these units are located at the Bruce-A and Bruce-B Nuclear Generating Stations, a 930-hectare (2,300-acre) site on Lake Huron about 300 kilometers (186 miles) northeast of Detroit, Michigan. The Bruce-A Nuclear Generating Station, which contains four 769-megawatt electric reactors, a common powerhouse with four turbine generators, a heavy water plant, a process steam transformer plant, a central services area, pumphouses, standby generators, and other support facilities, is used as the reference site for the disposition alternative evaluation. One or up to four of these units could be used for Plutonium (Pu) disposition for this alternative. The reference reactor MOX fuel cycle, adapting the standard CANDU fuel bundle in the four reactors, would dispose of approximately 2 metric tons/year (t/yr) of Pu (2.2 short tons [tons]/yr) and eliminate the mining and refining of approximately 6,000 t/yr (6,600 tons/yr) of uranium ore. The use of the CANDU reactors would be subject to the approval, policies, and regulations of the Canadian Federal and Provincial Governments. The fuel cycle is depicted in Figure I–1.

An alternate fuel bundle design using uranium fuel (the CANFLEX fuel bundle), which is currently undergoing reactor qualification, might be used. This fuel bundle has smaller diameter elements in the outer rings that would operate at a lower linear power rating, permitting higher Pu concentrations. Both designs have essentially the same Pu disposition capacity. The design is expected to reduce the number of fuel bundles and waste volumes by half.

The Bruce-A Nuclear Generating Station was selected as the reference plant for the following reasons:

- The reactor is designed without thermal neutron absorbing control rods to flatten power distribution in the central region of the core, a desirable attribute relative to thermal power margins. MOX fuel would perform in the same manner as natural uranium fuel in flattening the power distribution.

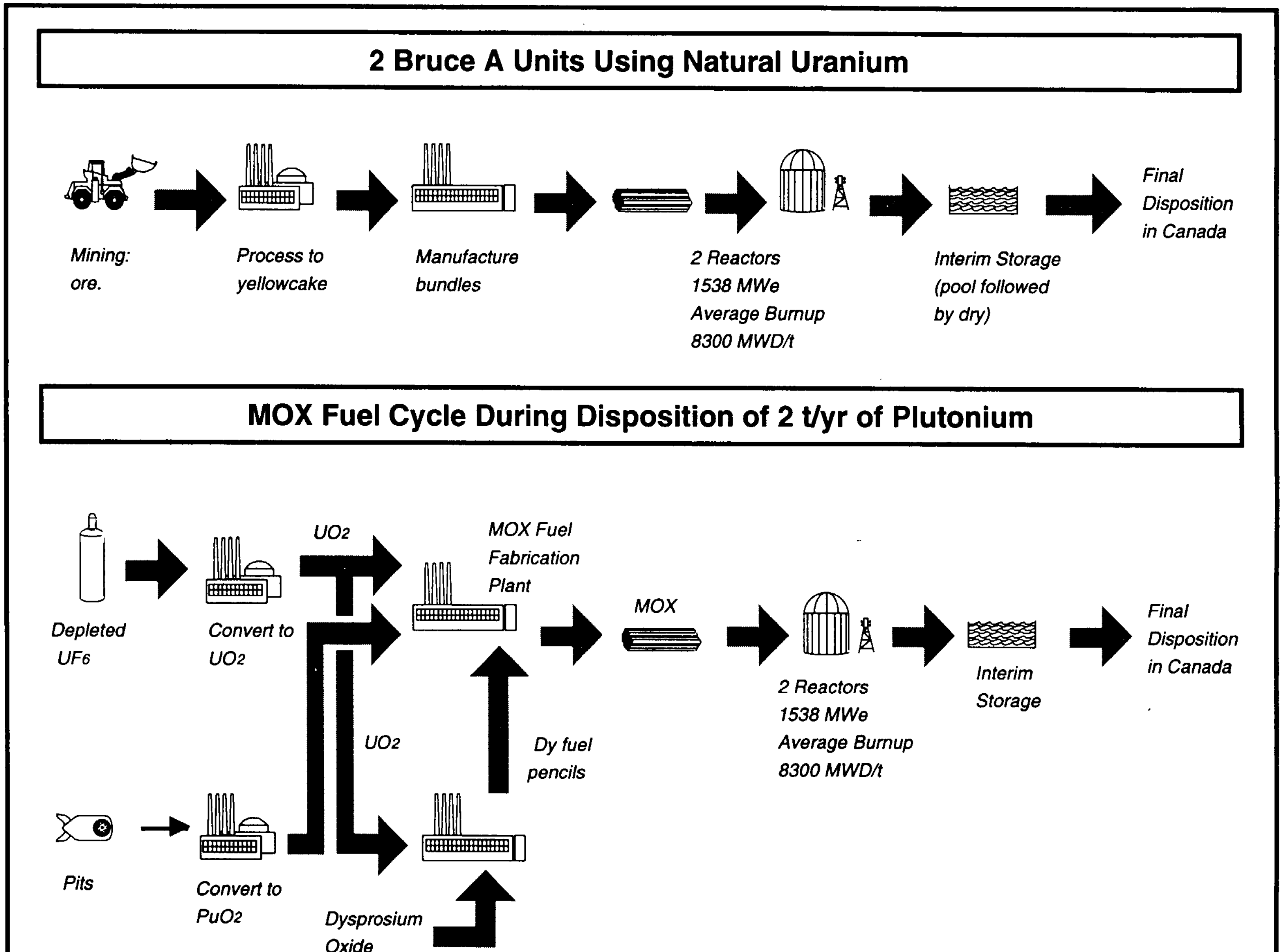
- The site is a base-load station that will maximize fuel consumption since reactors operate continually at or near their full load capability.

- The site is remote from population centers, yet relatively close to U.S.-Canadian border crossings for the shipment of MOX fuel from the United States.

- The site has current International Atomic Energy Agency approved safeguards and a Perimeter Intrusion Detection and Assessment System.

Reactor. Instead of a single large pressure vessel, the reference CANDU reactor has a horizontal, cylindrical, heavy water-filled, calandria tank containing 480 fuel channel assemblies (also referred to as tubes) and reactivity control units. Replacement of these tubes, "retubing," corresponds to core replacement in other reactors. The heavy water is the neutron moderator and reflector. This entire assembly is contained in the light water-filled shield tank to form an integral structure that provides operational and shutdown shielding.

Each fuel channel assembly consists of a zirconium-niobium alloy pressure tube contained within a zircaloy-2 calandria tube that provides a gas-filled, thermally insulated annulus separating the high pressure and high temperature heavy water coolant in the pressure tube from the low pressure and low temperature heavy water moderator in the calandria. Reactor neutron and gamma flux is attenuated through a latched steel shield plug mechanism inside the end fitting.



Note: MWe=megawatt electric; MWD=megawatt day; PuO_2=plutonium dioxide; UF_6=uranium hexafluoride; UO_2=uranium dioxide.
Source: ORNL 1995a.

2763/FMD

Figure I–1. Mixed Oxide Fuel Cycle.

Heat is removed by circulating heavy water coolant from the fuel channels to the steam generator, where it is transferred to the light water side. This system includes circulating pumps, headers, feeder pipes, the primary side of the steam generators, and preheaters. During operation, pressure is maintained by steam bleed valves connected to the pressurizer and immersion heaters within the pressurizer vessel.

The heavy water moderator circulates through the calandria and is cooled by heat exchangers. Moderator chemistry is maintained by the ion-exchange columns of the moderator purification circuit. Helium is the moderator cover gas.

Fourteen compartments within the reactor function as light water zone control units. These zones contain volumes of water, which are used to control reactor power. Self-powered, in-core neutron flux detectors located in each zone, along with channel thermal measurements, are used for power measurements by the reactor control system. On-power refueling and soluble neutron-absorbing material in the heavy water provide long-term reactivity control.

Steam from the secondary side of the steam generators is transferred to steam drums where it is routed to turbine generators. The turbines are tandem-compound, single-shaft machines that drive electrical generators. Each turbine has a double-flow, high-pressure chamber that discharges to a steam reheater that raises steam temperature for three double-flow, low- pressure chambers.

Fuel Handling and Storage. CANDU reactors can be refueled on-line. Operator consoles remotely control the fueling operation. A fueling duct traversed by two sets of transport trolley rails is used to move fresh MOX fuel to each reactor. In their loading area, new fuel bundles are placed in fueling machines that then pass through the containment wall port to fueling machine heads. At the reactor, the loading head is aligned with, and locks onto, the selected fuel channel end fitting. The loading head inserts new fuel bundles two at a time. At the other end of that channel, fuel bundles are displaced into a spent fuel head. After the required number of bundles has been placed in the channel the loading head is unlocked. This procedure is repeated until the designated channels are fueled. The irradiated fuel is discharged to the primary irradiated fuel storage bay. The spent fuel is stored here for a minimum of 6 months before it is transferred to the secondary irradiated fuel storage bay. The primary irradiated fuel storage bay can store 4 reactor years of fuel at an 80-percent capacity factor, while the storage capacity of the secondary bay is approximately 64 reactor years.

[Text deleted.]

Appendix J
Applicable Laws, Regulations, and Other Requirements

Compliance With Statutes, Regulations, and Other Associated Orders

Appendix J identifies the compliance requirements associated with the proposed action as specified by the major Federal and State Environment, Safety, and Health (ES&H) statutes, regulations, and orders.

Introduction and Purpose

This appendix provides enough information concerning the environmental standards and statutory requirements that impact the various alternatives for long-term storage and disposition of weapons-usable fissile materials to help make programmatic-level decisions. These statutes and regulations provide the standard with which the ability of candidate sites to meet ES&H requirements and the ability to obtain required Federal and State permits and licenses necessary to implement such decisions may be calculated. This appendix first provides an historical background on environmental protection at nuclear weapons production facilities. It then presents some of the more important requirements associated with the proposed action by identifying the applicable ES&H statutes, regulations, and orders. These are found in Federal and State statutes, regulations, permits, and approvals, as well as in Executive and Department of Energy (DOE) Orders. The remainder of this appendix explains the concept of shared Federal and State enforcement and summarizes compliance with occupational safety and health and environmental justice.

Compliance with the applicable requirements of each of the major ES&H statutes, regulations, and orders identified would allow DOE to construct and operate long-term storage and disposition facilities to meet such requirements. Sites have been selected for analysis as long-term storage locations. In contrast, since some of the proposed disposition alternatives are currently not tied to any one particular location, a "generic" site will be used for analysis. To be environmentally sound, programmatic decisions must also address the ES&H planning considerations described in Section 3.3 of the *Nuclear Weapons Complex Reconfiguration Study* (DOE/DP-0083). These considerations must also be met in order for the long-term storage and disposition alternatives to meet future ES&H requirements and to accomplish the mission in a timely and cost-effective manner.

Background

Since the majority of the past Complex facilities were constructed in the 1940s and 1950s, before the advent of today's environmental and worker health requirements, safety and the ability to satisfy national security requirements played the dominant roles in the design and operation of major industrial plants. However, with the emergence of an awareness of environmental and health-related issues and the enactment of environmental and worker health programs, DOE shifted a great deal of its resources into programs designed to achieve compliance with all applicable Federal, State, and local ES&H requirements. Today, many government agencies at the Federal, State, and local levels have regulatory authority over DOE's facility operations. DOE has entered into enforceable compliance agreements with the regulators at most of its facilities. These agreements detail specific programs, funding levels, and schedules for achieving compliance with applicable ES&H statutory and regulatory requirements. Because most of these agreements are constantly changing as subject agreements are completed, eliminated, or revised, a list has not been compiled for this programmatic environmental impact statement (PEIS).

All newly constructed and modified facilities must comply with the increasing number and complexity of environmental regulations. It is difficult to make facilities that are more than 40 years old comply quickly with constantly changing requirements. These older facilities generally do not meet all current standards for seismic

design, fire protection, and environmental protection (for example, air emissions, liquid effluents, and the management of solid and hazardous wastes). However, these facilities would be modernized to meet all applicable ES&H requirements now and into the 21st century, and a system would be developed to adequately manage the wastes generated by these facilities regardless of the proposed action addressed in this PEIS.

Environmental Statutes, Orders, and Agreements

The *Atomic Energy Act* (AEA) of 1954 authorizes DOE to establish standards to protect health and minimize dangers to life or property with respect to activities under its jurisdiction. The Nuclear Regulatory Commission (NRC) is charged under the AEA and the *Energy Reorganization Act* of 1974 with jurisdiction over commercial reactor construction and operation. NRC also licenses and regulates the possession, use, transportation, and disposal of radioactive materials, including wastes. NRC and Federal agencies such as the Department of Transportation also periodically review and revise their regulations to bring them generally to the same level as International Atomic Energy Agency regulations (Safety Series No. 6, revised 1990). This agency, under the United Nations, establishes standards for radioactive materials transportation. The Environmental Protection Agency (EPA), under authority of the AEA, has set radiation protection standards such as *Environmental Radiation Protection Standards for Nuclear Power Operations* (40 CFR 190). Most environmental regulations can be found under 40 Code of Federal Regulations (CFR). Because of their length, and for ease of reading, all tables in this chapter are presented consecutively at the end of the text. Table J–1 lists the applicable Federal environmental statutes, regulations, and Executive Orders, and also identifies the associated permit, approval, and consultation requirements generally required to implement an alternative for long term storage or disposition. Except for limited Presidential exemptions, Federal agencies must comply with all applicable provisions of Federal environmental statutes and regulations, in addition to all applicable State and local requirements. DOE is committed to complying fully with all applicable environmental statutes, regulatory requirements, and Executive and internal orders. Table J–2 lists the potential requirements imposed by the major State environmental statutes and regulations applicable to this predecisional PEIS. These requirements apply to Federal activities within the jurisdiction of the enforcing authority. Table J–2 identifies the permits, approvals, and consultations generally required to implement an alternative for long-term storage or disposition in accordance with State statutes and regulations. Table J–3 lists selected DOE ES&H Orders that apply to all sites, but which may affect each site differently. Table J–4 lists applicable NRC guidelines for the processing, use, transportation, and disposal of radioactive materials, including water.

Federal and State Environmental Enforcement

Some environmental regulatory programs are enforced through review, approval, and permitting requirements that attempt to minimize the negative impact of potential pollution sources' releases to the environment by limiting activities to established standards. Federal and State agencies share environmental regulatory authority over DOE's facility operations when Federal legislation delegates permitting or review authority to qualifying States. Some examples are the National Emission Standards for Hazardous Air Pollutants and the Prevention of Significant Deterioration under the *Clean Air Act;* the Water Quality Standards and the National Pollutant Discharge Elimination System under the *Clean Water Act;* the Hazardous Waste Programs under *Resource Conservation and Recovery Act* (RCRA); and the Drinking Water and Underground Injection Control Programs under the *Safe Drinking Water Act.* When Federal legislation allows enforcement authority to be delegated, States must set standards equal to or more stringent than those required by Federal law to obtain such authority. However, when Federal legislation does not allow enforcement authority to be delegated to the States (for example, the *Toxic Substance Control Act*), the standards are administered and enforced solely by the Federal Government.

Under various Federal environmental statutes (Table J-1), EPA may delegate the implementation and execution of the laws' various provisions to States with approved programs that are at least as stringent as the minimum

Federal requirements contained in the laws and EPA regulations. Table J–2 lists many of the States' laws and regulations, including provisions that are more stringent than the minimum requirements. In addition, the *Federal Facility Compliance Act* of 1992 waives sovereign immunity from the enforcement of RCRA at Federal facilities and thereby gives States the authority to assess fines and penalties under certain conditions.

Compliance with Occupational Safety and Health Requirements

The health and safety of all workers associated with the long-term storage and disposition alternatives is a primary consideration in this PEIS. A comprehensive nuclear and occupational safety and health initiative was announced by the Secretary on May 5, 1993, entailing closer consultation with the Occupational Safety and Health Administration (OSHA) regarding regulation of workers' safety and health at DOE's contractor-operated facilities. Regulation of workers', health and safety at DOE's contractor-operated facilities will gradually shift from DOE to OSHA. The *Occupational Safety and Health Act* of 1970, (Public Law 91-596) establishes Federal requirements for assuring occupational safety and health protection for employees. DOE's facilities also comply with the *Emergency Planning and Community Right-To-Know Act* (42 USC 11001), which requires facilities to report the release of extremely hazardous substances and other specified chemicals, provide Material Safety Data Sheets or lists thereof, and provide estimates of the amounts of hazardous chemicals onsite. The reporting and emergency preparedness requirements are designed to protect both individuals and communities.

Workplace Safety. Operations at all DOE sites expose workers to occupational hazards during the normal conduct of their work activities. Occupational safety and health training is provided for all employees at DOE facilities and includes specialized job safety and health training appropriate to the work performed. Such training also includes informing employees of their rights and responsibilities under the *Occupational Safety and Health Act* of 1970; Executive Order 12196, which established OSHA Federal Agency Standards; 29 CFR 1960, The OSHA Federal Agency Standards, which describes the safety and health programs that Federal agencies must establish and implement under Executive Order 12196; and DOE O 440.1, *Worker Protection Management for DOE Federal and Contractor Employees*. DOE provides implementation guidance in DOE O 440.1, including the requirements and guidelines for DOE employees.

DOE policy is the following:

- Provide places and conditions of employment that are as free as possible from recognized hazards that cause or are likely to cause illness or physical harm
- Consider 29 CFR 1960 (OSHA Standards for Federal Agencies) requirements to be the minimum standards for DOE employees
- Establish programs in safety and health training for all levels of Federal employees
- Assure that employees and employee representatives shall have the opportunity to participate in the Federal Employee Occupational Safety and Health Program

Workplace Accidents. DOE O 451.1, *National Environmental Policy Act Compliance Program*; DOE Order 5480.23, *Nuclear Safety Analysis Reports*; and DOE O 430.1, *Life-Cycle Asset Management* provide the basis for reviewing all planned and existing constructions and operations for the potential for accidents and assessing the associated human health and environmental consequences should an accident occur. The results of these reviews are used as the basis for determining the need for controls or other mitigative actions to eliminate or greatly reduce the potential for, and consequences of, an accident. These reviews are required before authorization of construction or start of operation. These reviews identify hazards and analyze normal, abnormal, and accident conditions. This analysis considers natural and manmade external events including fires, floods, tornadoes, earthquakes, other severe weather events, human errors, and explosions. The sites associated with the long-term storage and disposition proposal have complied with applicable DOE Orders.

In accordance with DOE O 151.1, *Comprehensive Emergency Management System*, emergency response planning and training are provided to mitigate the consequences of potential accidents. Additionally, should an accident occur, the incident would be reported in accordance with DOE O 232.1, *Occurrence Reporting and Processing of Operations Information*. The reports would also include appropriate corrective actions and follow-up.

Worker Health. DOE's contractor operations at each site expose workers to hazardous constituents. DOE Orders require that site operations have programs for protecting workers. DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, and DOE O 440.1, *Worker Protection Management for DOE Federal and Contractor Employees*, establish procedures for protecting workers against radiological and hazardous materials, respectively. DOE O 232.1, *Occurrence Reporting and Processing of Operations Information*, provides for reporting and guides appropriate corrective actions and follow-up should an exposure occur.

Consequences of the Weapons-Usable Fissile Materials Storage and Disposition Proposal on Candidate Site Workplace Safety and Accidents. Constructing and operating storage and disposition alternatives at potential candidate sites would result in site workers' increased exposure to industrial-type work hazards and accidents. In addition, the workers' level of risk in new construction increases in relation to the amount of changes required for such activities. Although constructing such facilities could result in injuries or fatalities, it is projected that the proposal for long-term storage and disposition will not cause any serious injuries or fatalities. All such incidences would be under the auspices of OSHA laws and regulations. Before implementing a long-term storage or disposition proposal at any site, however, the site's ES&H staff would be notified that a new process or facility is being planned, or that an existing process is being considered for change or modification to allow the impact of the anticipated change on the work environment to be evaluated.

Appropriate measures would be implemented to minimize work hazards and accidents based on this early evaluation. Once operational, as part of the Occupational Safety and Health Program at each site, ongoing surveillance of the new or modified processes or activities would be performed to identify potential health hazards. If potential health hazards are identified, a hazard evaluation would be conducted to determine the extent of the hazard and if required, the recommended control measures. Where feasible, engineering controls would be used to protect worker's health and safety. Appropriate administrative controls and personal protective equipment would supplement engineering controls.

Table J–1. ***Federal Environmental Statutes, Regulations, and Orders***

Resource Category	Statute/Regulation/Order	Citation	Responsible Agency	PEIS-Level Potential Applicability: Permits, Approvals, Consultations, and Notifications
Air Resources	CAA, as amended	42 USC 7401 et seq.	EPA	Requires sources to meet standards and obtain permits to satisfy: National Ambient Air Quality Standards, State Implementation Plans, Standards of Performance for New Stationary Sources, NESHAP, and PSD.
	National Ambient Air Quality Standards/State Implementation Plans	42 USC 7409 et seq.	EPA	Requires compliance with primary and secondary ambient air quality standards governing SO_2, NO_2, CO, O_3, Pb, and PM_{10} and emission limits/reduction measures as designated in each state's State Implementation Plan.
	Standards of Performance for New Stationary Sources	42 USC 7411	EPA	Establishes control/emission standards and recordkeeping requirements for new or modified sources specifically addressed by a standard.
	NESHAPs	42 USC 7412	EPA	Requires sources to comply with emission levels of carcinogenic or mutagenic pollutants; may require a preconstruction approval, depending on the process being considered and the level of emissions that will result from the new or modified source.
	PSD	42 USC 7470 et seq.	EPA	Applies to areas that are in compliance with National Ambient Air Quality Standards. Requires comprehensive preconstruction review and the application of Best Available Control Technology to major stationary sources (emissions of 100 t/yr) and major modifications; requires a preconstruction review of air quality impacts and the issuance of a construction permit from the responsible state agency setting forth emission limitations to protect the PSD increment.
	Noise Control Act of 1972	42 USC 4901 et seq.	EPA	Requires facilities to maintain noise levels that do not jeopardize the health and safety of the public.
Water Resources	CWA	33 USC 1251 et seq.	EPA	Requires EPA or State-issued permits and compliance with provisions of permits regarding discharge of effluents to surface waters.
	NPDES (section 402 of CWA)	33 USC 1342	EPA	Requires permit to discharge effluents (pollutants) to surface waters and stormwaters; permit modifications are required if discharge effluents are altered.
	Dredged or Fill Material - (section 404 of CWA/ *Rivers and Harbors Appropriations Act* of 1899	33 USC 1344 33 USC 401 et seq.	U.S. Army Corps of Engineers	Requires permits to authorize the discharge of dredged or fill material into navigable waters or wetlands and to authorize certain structures or work in or affecting navigable waters.

Table J-1. Federal Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Statute/Regulation/Order	Citation	Responsible Agency	PEIS-Level Potential Applicability: Permits, Approvals, Consultations, and Notifications
Water Resources (continued)	*Wild and Scenic Rivers Act*	16 USC 1271 et seq.	United States Fish and Wildlife Service (USFWS), Bureau of Land Management, Forest Service, National Park Service	Consultation required before construction of any new Federal project associated with a river designated as wild and scenic or under study in order to minimize and mitigate any adverse effects on the physical and biological properties of the river.
	SDWA	42 USC 300f et seq.	EPA	Requires permits for construction/operation of underground injection wells and subsequent discharging of effluents to ground aquifers.
	Executive Order 11988: Floodplain Management	3 CFR, 1977 Comp., p. 117	Water Resources Council, Federal Emergency Management Agency, Council on Environmental Quality	Requires consultation if project impacts a floodplain.
	Executive Order 11990: Protection of Wetlands	3 CFR, 1977 Comp., p. 121	U.S. Army Corps of Engineers/USFWS	Requires Federal agencies to avoid the long- and short-term adverse impacts associated with the destruction or modification of wetlands.
	Compliance with Floodplain/Wetlands Environmental Review Requirements	10 CFR 1022	DOE	Requires DOE to comply with all applicable floodplain/wetlands environmental review requirements.
Hazardous Wastes and Soil Resources	RCRA /Hazardous and Solid Waste Amendments of 1984	42 USC 6901 et seq./PL 98-616	EPA	Requires notification and permits for operations involving hazardous waste treatment, storage, or disposal facilities; changes to site hazardous waste operations could require amendments to RCRA hazardous waste permits involving public hearings.
	CERCLA of 1980/SARA of 1986	42 USC 9601 et seq./PL 99-499	EPA	Requires cleanup and notification if there is a release or threatened release of a hazardous substance; requires DOE to enter into Interagency Agreements with EPA and State to control the cleanup of each DOE site on the NPL.
	Federal Land Policy and Management Act	43 USC 1701	Federal and State land-planning agencies	Requires Federal and/or State land-planning agencies to retain Federal ownership of public lands unless it is determined that disposal as such parcel will serve the national interest.

Table J–1. Federal Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Statute/Regulation/Order	Citation	Responsible Agency	PEIS-Level Potential Applicability: Permits, Approvals, Consultations, and Notifications
Hazardous Wastes and Soil Resources (continued)	NWPA of 1982	42 USC Section 10101-10270	Federal Agencies	Establishes a schedule for the siting, construction, and operation of repositories that will provide a reasonable assurance that the public and the environment will be protected from the hazards posed by disposal of high-level radioactive waste and SNF; establishes the Federal responsibility, and a definite Federal policy for the disposal of HLW and SNF; defines the relationship between the Federal and State government with respect to the disposal of HLW and SNF; and establishes a Nuclear Waste Fund.
	Community Environmental Response Facilitation Act	PL 102-426	EPA	Amends CERCLA (40 CFR 300) to establish a process for identifying, prior to the termination of Federal activities, property that does not contain contamination. Requires prompt identification of parcels that will not require remediation to facilitate the transfer of such property for economic redevelopment purposes.
	Farmland Protection Policy Act of 1981	7 USC 4201 et seq.	Soil Conservation Service	DOE shall avoid any adverse effects to prime and unique farmlands.
	Federal Facility Compliance Act of 1992	42 USC 6961	States	Waivers of sovereign immunity for Federal facilities under RCRA and requires DOE to develop plans and enter into agreements with states as to specific management actions for specific mixed waste streams.
Biotic Resources	*Fish and Wildlife Coordination Act*	16 USC 661 et seq.	USFWS	Requires consultation on the possible effects on wildlife if there is construction, modification, or control of bodies of water in excess of 10 acres in surface area.
	Bald and Golden Eagle Protection Act	16 USC 668 et seq.	USFWS	Consultations should be conducted to determine if any protected birds are found to inhabit the area. If so, DOE must obtain a permit prior to moving any nests due to construction or operation of storage or disposition facilities.
	Migratory Bird Treaty Act	16 USC 703 et seq.	USFWS	Requires consultation to determine if there are any impacts on migrating bird populations due to construction or operation of storage or disposition facilities. If so, DOE will develop mitigation measures to avoid adverse effects.
	Anadromous Fish Conservation Act	16 USC 757	USFWS	Requires consultation to determine if there are any impacts on anadromous fish that spawn in fresh water or estuaries and migrate to ocean waters and on anadromous fishery resources that are subject to deplete from water resource development.
	Wilderness Act of 1964	16 USC 1131 et seq.	DOC and DOI	DOE shall consult with the Department of Commerce and the Department of Interior and minimize impact.
	Wild Free-Roaming Horses and Burros Act of 1971	16 USC 1331 et seq.	DOI	DOE shall consult with the Department of Interior and minimize impact.

Table J-1. Federal Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Statute/Regulation/Order	Citation	Responsible Agency	PEIS-Level Potential Applicability: Permits, Approvals, Consultations, and Notifications
Biotic Resources (continued)	*Endangered Species Act* of 1973	16 USC 1531 et seq.	USFWS/National Marine Fisheries Service	Requires consultation to identify endangered or threatened species and their habitats, assess DOE impacts thereon, obtain necessary biological opinions and, if necessary, develop mitigation measures to reduce or eliminate adverse effects of construction or operation.
Cultural Resources	*National Historic Preservation Act* of 1966, as amended	16 USC 470 et seq.	President's Advisory Council on Historic Preservation	DOE shall consult with the State Historic Preservation Office prior to construction to ensure that no historical properties will be affected.
	Archaeological and Historical Preservation Act of 1974	16 USC 469 et seq.	DOI	DOE shall obtain authorization for any disturbance of archaeological resources.
	Archaeological Resources Protection Act of 1979	16 USC 470aa et seq.	DOI	DOE shall obtain authorization for any excavation or removal of archaeological resources.
	American Indian Religious Freedom Act of 1978	42 USC 1996	DOI	DOE shall consult with local Native American Indian tribes prior to construction to ensure that their religious customs, traditions, and freedoms are preserved.
	Native American Graves Protection and Repatriation Act of 1990	25 USC 3001	DOI	DOE shall consult with local Native American Indian tribes prior to construction to guarantee that no Native American graves are disturbed.
	Executive Order 11593: Protection and Enhancement of the Cultural Environment	3 CFR 154, 1971-1975 Comp., p. 559	DOI	DOE shall aid in the preservation of historic and archaeological data that may be lost during construction activities.
Worker Safety and Health	*Occupational Safety and Health Act*	5 USC 5108	OSHA	Agencies shall comply with all applicable worker safety and health legislation (including guidelines of 29 CFR 1960) and prepare, or have available, Material Safety Data Sheets.
	OSHA Guidelines	29 USC 660	OSHA	Agencies shall comply with all applicable worker safety and health legislation (including guidelines of 29 CFR 1960) and prepare, or have available, Material Safety Data Sheets.
	Hazard Communication Standard	29 CFR 1910.1200	OSHA	DOE shall ensure that workers are informed of, and trained to handle, all chemical hazards in the DOE workplace.
Other	*Atomic Energy Act* of 1954	42 USC 2011	DOE	DOE shall follow its own standards and procedures to ensure the safe operation of its facilities.
	NEPA	42 USC 4321 et seq.	CEQ	DOE shall comply with NEPA implementing procedures in accordance with 10 CFR 1021.
	Department of Energy NEPA Implementing Regulations	DOE 10 CFR Parts 1-199 (applicable sections), 820, 830, 835	DOE	DOE shall follow its own implementing regulations to ensure quality assurance, NRC agreements, and health and safety procedures.

Table J–1. Federal Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Statute/Regulation/Order	Citation	Responsible Agency	PEIS-Level Potential Applicability: Permits, Approvals, Consultations, and Notifications
Other (continued)	TSCA	15 USC 2601 et seq.	EPA	DOE shall comply with inventory reporting requirements and chemical control provisions of TSCA to protect the public from the risks of exposure to chemicals; TSCA imposes strict limitations on use and disposal of PCB-contaminated equipment.
	Hazardous Materials Transportation Act	49 USC 1801 et seq.	DOT	DOE shall comply with the requirements governing hazardous materials and waste transportation.
	Hazardous Materials Transportation Uniform Safety Act of 1990	49 USC 1801	DOT	Restricts shippers of highway route-controlled quantities of radioactive materials to use only permitted carriers.
	Emergency Planning and Community Right-To-Know Act of 1986	42 USC 11001 et seq.	EPA	Requires the development of emergency response plans and reporting requirements for chemical spills and other emergency release, and imposes right-to-know reporting requirements covering storage and use of chemicals that are reported in toxic chemical release forms.
	Executive Order 12088: Federal Compliance with Pollution Control Standards	3 CFR, 1978 Comp., p. 243	Office of Management and Budget (OMB)	Requires Federal agency landlords to submit to OMB an annual plan for the control of environmental pollution and to consult with EPA and State agencies regarding the best techniques and methods.
	Executive Order 11514: Protection and Enhancement of Environmental Quality	3 CFR, 1966-1970 Comp., p. 902	CEQ	Requires Federal agencies to demonstrate leadership in achieving the environmental quality goals of NEPA; provides for DOE consultation with appropriate Federal, State, and local agencies in carrying out their activities as they affect the environment.
	Pollution Prevention Act of 1990	42 USC 11001-11050	EPA	Establishes a national policy that pollution should be reduced at the source and requires a toxic chemical source reduction and recycling report for an owner or operator of a facility required to file an annual toxic chemical release form under section 313 of SARA.
	Executive Order 11988: Floodplain Management	3 CFR 1977 Comp., p. 117	Var. Agencies and EPA	Directs Federal agencies to establish procedures to ensure that the potential effects of flood hazards and floodplain management are considered for any action undertaken in a floodplain and that floodplain impacts be avoided to the extent practicable.
	Executive Order 12114: Environment Affects Abroad Major Federal Actions	January 4, 1979	DOE	Requires officials of Federal agencies having ultimate responsibility for authorizing and approving actions encompassed by this Order to be informed of pertinent environmental considerations and to take such considerations into account, with other pertinent considerations of national policy in making decisions regarding such actions. While based on independent authority, this Order furthers the purpose of NEPA.

Table J-1. Federal Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Statute/Regulation/Order	Citation	Responsible Agency	PEIS-Level Potential Applicability: Permits, Approvals, Consultations, and Notifications
Other (continued)	Executive Order 12372: Intergovernmental review of federal programs	July 14, 1982	DOE	Requires Federal agencies to provide opportunities for consultation by elected officials of those State and local governments that would provide the non-Federal funds for or that would be directly affected by proposed Federal financial assistance or direct Federal development.
	Executive Order 12843: Procurement Requirements and Policies for Federal Agencies for Ozone-Depleting Substances	April 21, 1993	EPA	Requires Federal agencies to minimize procurement of ozone-depleting substances and conform their practices to comply with Title VI of CAA Amendments reference stratospheric ozone protection and to recognize the increasingly limited availability of Class I substances until final phaseout.
	Executive Order 12856: Federal Compliance with Right-To-Know Laws and Pollution Prevention Requirements	August 3, 1993	EPA	Requires Federal agencies to achieve 50 percent reduction of agency's total releases of toxic chemicals to the environment and offsite transfers, to prepare a written facility pollution prevention plan not later than 1995, and to publicly report toxic chemicals entering any waste stream from Federal facilities, including any releases to the environment, and to improve local emergency planning, response and accident notification.
	Executive Order 12873: Federal Acquisition, Recycling, and Waste Prevention	October 20, 1993	EPA	Requires Federal agencies to develop affirmative procurement policies and establishes a shared responsibility between the system program manager and the recycling community to effect use of recycled items for procurement.
	Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations	February 11, 1994	EPA	Requires Federal agencies to identify and address as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations.
	Executive Order 12580: Superfund Implementation	January 23, 1987	Executive Depts. and DOE	Delegates to the heads of executive departments and agencies the responsibility for undertaking remedial actions for releases, or threatened releases that are not on the NPL and removal actions other than emergencies where the release is from any facility under the jurisdiction or control of executive departments and agencies
	Executive Order 12856: Right to Know Laws and Pollution Prevention Requirements	August 3, 1993	DOE	Directs all Federal agencies to reduce and report toxic chemicals entering any wastestream; improve emergency planning, response, and accident notification; and encourage clean technologies and testing of innovative prevention technologies. The executive order also provides the Federal agencies are persons for purposes of the *Emergency Planning and Community Right-to-Know Act* (SARA Title iii), which obliges agencies to meet the requirements of the Act.

Table J–1. Federal Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Statute/Regulation/Order	Citation	Responsible Agency	PEIS-Level Potential Applicability: Permits, Approvals, Consultations, and Notifications
Other (continued)	Executive Order 10480: Further Providing for the Administration of the Defense Mobilization Program	August 1953	Federal Emergency Management Agency	Delegates to the Director, Federal Emergency Management Agency with authority to redelegate, the priorities and allocation functions conferred on the President by Title I of the *Defense Production Act* of 1950, as amended.
	Executive Order 12148: Federal Emergency Management	July 20, 1979	Federal Emergency Management Agency	Transferred functions and responsibilities associated with Federal emergency management to the Director, Federal Emergency Management Agency. The Order assigns the Director, Federal Emergency Management Agency, the responsibility to establish Federal policies for and to coordinate all civil defense and civil emergency planning, management, mitigation, and assistance functions of Executive Agencies.
	Executive Order 12472: Assignment of National Security and Emergency Preparedness Telecommunications Function	April 3, 1984	DOE	Establishes the National Communication System. The National Communication System consists of the telecommunications assets of the entities represented on the National Communication System Committee of Principals and an administrative structure consisting of the Executive Agent, the National Communication System Committee of Principals, and the Manager.
	Executive Order 12656: Assignment of Emergency Preparedness Responsibilities	November 1988	DOE	This order assigns emergency preparedness responsibilities to Federal departments and agencies.
	Low-Level Radioactive Waste Policy Act	42 USC 2021b-2021d	DOE	DOE shall dispose of LLW per compacts of the states in which it operates.

Table J-2. State Environmental Statutes, Regulations, and Orders

Resource Category	Legislation	Citation	Responsible Agency	Potential Applicability/Permits
Hanford, Washington State				
Air Resources	*Washington Clean Air Act*	Revised Code of Washington (RCW) Chapter 70.94	WA Department of Ecology	Required to register and obtain permits for new resources.
	Noise Control Act of 1974	RCW, Ch 70.107	WA Department of Ecology	Required to comply with anti-noise measures.
Water Resources	*Coastal Waters Protection Act* of 1971	RCW, Ch. 90.48	WA Department of Ecology	Water pollution control requirements; applies to all waters of the State.
	Chemical Contaminants and Water Quality	RCW, Ch. 70.142	WA Department of Ecology	Water pollution control requirements.
	Water Rights of the United States	RCW, Ch. 90.40	NA	Federal eminent domain.
Hazardous Wastes and Soil Resources	*Hazardous Waste Management Act*	RCW, Ch. 70.105	WA Department of Ecology	Permits required for various activities involving hazardous waste.
	Nuclear Energy and Radiation	RCW, Ch. 70.98	WA Department of Ecology	Licensing and permitting of radiation sources.
	Radioactive Waste Storage and Transport Act of 1980	RCW, Ch. 70.99	WA Department of Ecology	Establishes various requirements for handling and storage of rad waste.
	Radioactive Waste Act	RCW, Ch. 43.200	WA Department of Ecology	Establishes various requirements for handling and storage of rad waste.
Biotic Resources	Various Acts Concerning Fish and Game	RCW, Ch. 77	WA Department of Fish and Wildlife	May require consultation with responsible agency.
Other	*State Environmental Policy Act*	RCW, Ch. 43.21C	WA Department of Ecology	Required to prepare "detailed statement" on environmental impacts of proposed actions.
	Underground Tanks	WAC, Ch. 173-360	WA Department of Ecology	Required to follow regulations if underground storage tanks involved in project.
Cultural resources	Archaeology and Historic Preservation	RCW, Ch. 43.51A	WA Office of Archaeology and Historic Preservation	Required to follow rules designated to protect state cultural resources.
INEL, Idaho				
Air Resources	*Idaho Environmental Protection and Health Act*	ID Code, Title 39, Chapter 101	ID Department of Health and Welfare	Permit required prior to construction or modification of an air contaminant source.
	Idaho Department of Health and Welfare Rules	ID Code, Title 39, Chapter 1	ID Department of Health and Welfare	Permit required prior to construction or modification of an air contaminant source.
Water Resources	Idaho Wastewater-Land Application Permit Regulations	ID Rules/Regs., Title 1, Chapter 17	ID Department of Health and Welfare	Permit required prior to construction or modification of a water discharge source.
	Idaho Water Pollution Control Act	ID Code, Title 39, Chapter 36	ID Department of Health and Welfare	Permit required prior to construction or modification of a water discharge source.

Table J-2. State Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Legislation	Citation	Responsible Agency	Potential Applicability/Permits
	Idaho Water Quality Standards	ID Rules/Regs., Title 1, Chapter 2	ID Department of Water Resources, Resource Administration Division	Permit required prior to the construction or operation of a wastewater injection well.
	Idaho Stream Channel Protection Act	ID Code, Title 42, Chapter 38	ID Department of Water Resources	Permit required prior to dredge or fill of any stream.
	Idaho Lake Protection Act	ID Code, Section 58-142 et seq.	ID Department of Lands	Permit required prior to dredge or fill of any lake.
Hazardous Wastes and Soil Resources	*Idaho Hazardous Waste Management Act*	ID Code, Title 39, Chapter 44	ID Department of Health and Welfare	Permit required prior to construction or modification of a hazardous waste disposal facility.
	Idaho Hazardous Waste Management Regulations	ID Rules/Regs., Title 1, Chapter 5	ID Department of Health and Welfare	Permit required prior to construction or modification of a hazardous waste disposal facility.
Biotic Resources	Various Acts Regarding Fish and Game	ID Code, Title 36	ID Department of Fish and Game	May require consultation with responsible agency.
Cultural Resources	*Idaho Historic Preservation Act*	ID Code, Title 67, Chapter 46	ID Historic Preservation Commission	Consult with responsible local governing body.
Los Alamos National Laboratory, New Mexico				
Air Resources	*New Mexico Air Quality Control Act*	NM Stat., Title 74, Article 2	NM Health and Environmental Department	Permit required prior to the construction or modification of an air contaminant source.
	New Mexico Air Quality Standards and Regulations	NM Air Quality Control Regs., 100	NM Health and Environmental Department	Permit required prior to the construction or modification of an air contaminant source.
Water Resources	*New Mexico Water Quality Act*	NM Stat., Title 74, Article 6	NM Water Quality Control Com.	Permit required prior to the construction or modification of a water discharge source.
	New Mexico Water Quality Regulations	NM Water Regulations	NM Water Quality Control Com.	Permit required prior to the construction or modification of a water discharge source.
Hazardous Wastes and Soil Resources	*New Mexico Solid Waste Act*	NM Stat., Chap. 74, Article 8	NM Health and Environmental Dept.	Permit required prior to the construction or modification of a solid waste disposal facility.
	New Mexico Solid Waste Management Regulations	NM Solid Waste Mgmt. Regs.	NM Environmental Improvement Div.	Permit required prior to the construction or modification of a solid waste disposal facility.

Table J–2. State Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Legislation	Citation	Responsible Agency	Potential Applicability/Permits
	New Mexico Hazardous Waste Management Regulations	NM Hazardous Waste Mgmt. Regs.	NM Environmental Improvement Div.	Permit required prior to the construction or modification of a hazardous waste disposal facility.
	New Mexico Underground Storage Tank Regulations	NM Underground Storage Tank Regulations	NM Health and Environmental Dept.	Permit required to comply with tank requirements prior to the construction or modification of an underground storage tank.
Biotic Resources	*New Mexico Wildlife Conservation Act*	NM State Act 1978, Sections 17–2–37 through 17–2–46	NM Department of Game and Fish	Permit and coordination required if a project may disturb habitat or otherwise affect threatened or endangered species.
	New Mexico Endangered Plant Species Act	NM State Act 1978, Sections 75–6–1	NM State Forestry Department	Coordination with the department required.
Cultural Resources	*New Mexico Cultural Properties Act*	NM State Act 1978, Sections 18–6–23	NM State Historic Preservation Office	Established State Historic Preservation Office and requirements to prepare an archaeological and historic survey and consult with the State Historic Preservation Office.
Worker Safety and Health	No state-level legislation identified	NA	NA	NA
NTS, Nevada				
Air Resources	Nevada Air Pollution Control Law	NV Statutes, Title 40	NV State Environmental Commission	Permit required prior to construction or modification of an air contaminant source.
	Nevada Air Quality Regulations	NV Admin. Code, Chapter 445	NV State Environmental Commission	Permit required prior to construction or modification of an air contaminant source.
Water Resources	Nevada Water Pollution Control Law	NV Statutes, Title 40, Chapter 445	NV Department of Environmental Protection	Permit required prior to construction or modification of a water discharge source.
	Nevada Water Pollution Control Regulations	NV Admin. Code, Chapter 445	NV Department of Environmental Protection	Permit required prior to construction or modification of a water discharge source.
Hazardous Wastes and Soil Resources	Nevada Underground Storage Tank Rules	NV Admin. Code, Chapter 459	NV Department of Environmental Protection	Permit required prior to construction or modification of an underground storage tank.
	Nevada Solid Waste Disposal Law	NV Statutes, Title 40, Chapter 444	NV Department of Environmental Protection	Permit required prior to construction or modification of a solid waste disposal facility.

Table J–2. State Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Legislation	Citation	Responsible Agency	Potential Applicability/Permits
	Nevada Solid Waste Disposal Regulations	NV Admin. Code, Chapter 44	NV Department of Environmental Protection	Permit required prior to construction or modification of a solid waste disposal facility; permit for septage hauling may be required.
	Nevada Hazardous Waste Disposal Law	NV Statutes, Title 40, Chapter 459	NV Department of Environmental Protection	Permit required prior to construction or modification of a hazardous waste disposal facility.
	Nevada Hazardous Waste Facility Regulations	NV Admin. Code, Chapter 444	NV Department of Environmental Protection	Permit required prior to construction or modification of a hazardous waste disposal facility.
Biotic Resources	*Nevada Non-Game Species Act*	NV Admin. Code, Title 45, Chapter 503	NV Department of Wildlife	Consult with NV Department of Wildlife and minimize impact.
Cultural Resources	Historic Preservation and Archaeology Regulations	NV Statutes, Title 26, Chapter 381-383	NV Advisory Board for Historic Preservation and Archaeology	Permit required prior to the investigation, exploration, or excavation of a historic or prehistoric site.
ORR, Tennessee				
Air Resources	Tennessee Air Pollution Control Regulations	TN Rules, Division of Air Pollution	TN Air Pollution Control Board	Permit required to construct, modify, or operate an air contaminant source; sets fugitive dust requirements.
Water Resources	*Tennessee Water Quality Control Act*	TN Code, Title 69, Chapter 3	TN Water Quality Control Board	Authority to issue new or modify existing NPDES permits required for a water discharge source.
Hazardous Wastes and Soil Resources	Tennessee Underground Storage Tank Program Regulations	TN Rules, Chapter 1200-1-15	TN Division of UST Programs	Permit required prior to construction or modification of an underground storage tank.
	Tennessee Hazardous Waste Management Act	TN Code, Title 68, Chapter 46	TN Division of Solid Waste Management	Permit required to construct, modify, or operate a hazardous waste treatment, storage, or disposal facility.
	Tennessee Solid Waste Processing and Disposal Regulations	TN Rules, Chapter 1200-1-7	TN Division of Solid Waste Management	Permit required to construct or operate a solid waste processing or disposal facility.

Table J-2. State Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Legislation	Citation	Responsible Agency	Potential Applicability/Permits
Biotic Resources	Tennessee State Executive Order on Wetlands	TN State Executive Order	TN Division of Water Quality Control	Consultation with responsible agency.
	Tennessee Threatened Wildlife Species Conservation Act of 1974	TN Code, Title 70, Chapter 8	TN Wildlife Resources Agency	Consultation with responsible agency.
	Tennessee Rare Plant Protection and Conservation Act of 1985	TN Code, Title 70, Chapter 8-301 et seq.	TN Wildlife Resources Agency	Consultation with responsible agency.
	Tennessee Water Quality Control Act	TN Code, Title 69, Chapter 3	TN Division of Water Quality Control	Permit required prior to alteration of a wetland.
Cultural Resources	Tennessee Desecration of Venerated Objects	TN Code, Title 39, Chapter 17-311	TN Historical Commission	Forbids a person to offend or intentionally desecrate venerated objects including a place of worship or burial.
Pantex, Texas				
Air Resources	Texas Air Pollution Control Regulations	TX Admin. Code, Title 30, Chapter 101-125, 305	Texas Natural Resource Conservation Commission (TNRCC) (effective 9/1/93)	Permit required prior to construction or modification of an air contaminant source.
Water Resources	Texas Water Quality Standards	TX Admin. Code, Title 30, Chapter 305, 308-325	TNRCC (effective 9/1/93)	A permit may be required prior to any modification of waters of the State including stream alteration for the construction of intakes, discharges, bridges, submarine utility crossings, etc. discharge source.
	Texas Consolidated Permit Rules	TX Admin. Code, Title 30	TNRCC (effective 9/1/93)	Permit required prior to construction or modification of a water discharge source.
	Texas Water Quality Acts	TX Code, Title 30, Chapter 290	TNRCC (effective 9/1/93)	Permit required prior to construction or modification of a water discharge source affecting a public water supply.
Hazardous Wastes and Soil Resources	Texas Underground Storage Tanks Rules	TX Admin. Code, Title 30, Chapter 334	TNRCC (effective 9/1/93)	Permit required prior to construction or modification of an underground storage tank.
	Texas Solid Waste Management Regulations	TX Admin. Code, Title 30, Chapter 305, 335	TNRCC (effective 9/1/93)	Permit required prior to construction or modification of a solid waste disposal facility.
	Texas Solid Waste Disposal Act	TX Statutes, Article 4477-7	TNRCC (effective 9/1/93)	Permit required prior to construction or modification of a solid waste disposal facility.

Table J–2. State Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Legislation	Citation	Responsible Agency	Potential Applicability/Permits
Biotic Resources	Texas Parks and Wildlife Regulations	TX Parks and Wildlife Code, Chapters 67, 68, & 88	TX Parks and Wildlife Department	Permit required by anyone who possesses, takes, or transports endangered, threatened, or protected plants or animals.
Cultural Resources	Antiquities Code of Texas	TX Statutes, Volume 17, Article 6145	TX State Historical Survey Committee	Permit required for the examination or excavation of sites and the collection or removal of objects of antiquity.
	Tennessee Abuse of Corpse	TN Code, Title 39, Chapter 17-312	TX Historical Commission	Forbids a person from disinterring a corpse that has been buried or otherwise interred.
	Native American Indian Cemetery Removal and Reburial	TN Comp. Rules and Regulations, Chapter 400-9-1	TX Historical Commission	Requires notification if Native American Indian remains are uncovered.
	Tennessee Protective Easements	TN Code, Title 11, Chapter 15-101	TX State Government	Grants power to the State to restrict construction on land deemed as a "protective" easement.
RFETS, Colorado				
Air Resources	*Colorado Air Quality Control Act*	Colorado Revised Statutes (CRS) Title 25, Article 7	CO Air Quality Control Comm.	Required to follow emission control regulations.
Water Resources	*Colorado Water Quality Control Act*	CRS, Title 25, Article 8	CO Water Quality Control Comm.	Required to follow regulations governing water quality.
Hazardous wastes and soil resources	Hazardous waste management, storage, and disposal	CRS, Title 25, Article 15, Part 3	CO Department of Health	Permits required for various activities involving hazardous waste.
Biotic resources	*Nongame, Endangered, and Threatened Species Act*	CRS, Title 33, Article 2	CO Division of Wildlife; Wildlife Commission	May require consultation with responsible agency.
Other	Underground Storage Tanks	CRS, Title 8, Article 20, Part 5; Title 25, Article 18	CO State Inspector of Oils	Required to follow regulations concerning underground storage tanks.
Cultural Resources	State history, archives, and emblems	CRS, Title 24, Article 80	CO Historical Society	Required to follow laws to protect state historical/archaeological resources.

Table J–2. State Environmental Statutes, Regulations, and Orders—Continued

Resource Category	Legislation	Citation	Responsible Agency	Potential Applicability/Permits
SRS, South Carolina				
Air Resources	*South Carolina Pollution Control Act*/South Carolina Air Pollution Control Regulations and Standards	SC Code, Title 48, Chapter 1	SC Department of Health and Environmental Control	Permit required prior to construction or modification of an air contaminant source.
	Augusta-Aiken Air Quality Control Region	40 CFR 81.114	SC and GA Department of Health and Environmental Control	Requires SRS and surrounding communities in the two-State region to attain NAAQS.
	South Carolina Atomic Energy & Radiation Control Act	SC Code, Title 13, Chapter 7	SC Department of Health and Environmental Control	Establishes standards for radioactive air emissions.
Water Resources	*South Carolina Pollution Control Act*	SC Code, Title 48, Chapter 1	SC Department of Health and Environmental Control	Permit required prior to construction or modification of a water discharge source.
	South Carolina Water Quality Standards	SC Code, Title 61, Chapter 68	SC Department of Health and Environmental Control	Permit required prior to construction or modification of a water discharge source.
	South Carolina Safe Drinking Water Act	SC Code, Title 44, Chapter 55	SC Department of Health and Environmental Control	Establishes drinking water standards.
Hazardous Wastes and Soil Resources	*South Carolina Underground Storage Tanks Act*	SC Code, Title 44, Chapter 2	SC Department of Health and Environmental Control	Permit required prior to construction or modification of an underground storage tank.
	South Carolina Solid Waste Regulations	SC Code, Title 61, Chapter 60	SC Department of Health and Environmental Control	Permit required to store, collect, dispose, or transport solid wastes.
	South Carolina Industrial Solid Waste Disposal Site Regulations	SC Code, Title 61, Chapter 66	SC Pollution Control Authority	Permit required for industrial solid waste disposal systems.
	South Carolina Hazardous Waste Management Act	SC Code, Title 44, Chapter 56	SC Department of Health and Environmental Control	Permit required to operate, construct, or modify a hazardous waste treatment, storage, or disposal facility.
	South Carolina Solid Waste Management Act	SC Code, Title 44, Chapter 96	SC Department of Health and Environmental Control	Establishes standards to treat, store, or dispose of solid waste.
Biotic Resources	*South Carolina Nongame and Endangered Species Conservation Act*	SC Code, Title 50, Chapter 15	SC Wildlife and Marine Resources Department	Consult with Wildlife and Marine Resources Department and minimize impact.
Cultural Resources	South Carolina Institute of Archaeology and Anthropology	SC Code, Title 60, Chapter 13-210	SC State Historic Preservation Office	Consult with State Historic Preservation Office and minimize impact.

Note: NA=not applicable.

Table J–3. Selected Department of Energy Environment, Safety, and Health Orders

DOE Order	Order Title
O 151.1	Comprehensive Emergency Management System
O 210.1	Performance Indicators and Analysis of Operations Information
O 225.1	Accident Investigations
O 231.1	Environment, Safety, and Health Reporting
O 232.1	Occurrence Reporting and Processing of Operation Information
O 360.1	Training
O 420.1	Facility Safety
O 425.1	Startup and Restart of Nuclear Facilities
O 430.1	Life-Cycle Assets Management
O 440.1	Worker Protection Management for DOE Federal and Contractor Employees
O 440.2	Aviation
N 441.1	Radiological Protection for DOE Activities
O 451.1	*National Environmental Policy Act* Compliance Program
O 452.1	Nuclear Explosive and Weapons Surety
O 452.2	Safety of Nuclear Explosive Operations
O 460.1	Packaging and Transportation Safety
O 460.2	Departmental Materials Transportation and Packaging Management
O 470.1	Safeguards and Security Program
O 471.2	Information Security Program
O 472.1	Personnel Security Activities
1300.2A	Department of Energy Technical Standards Program
1360.2B	Unclassified Computer Security Program
3790.1B	Federal Employee Occupational Safety and Health Program
4330.4B	Maintenance Management Program
4700.1	Project Management System
5400.1	General Environmental Protection Program
5400.5	Radiation Protection of the Public and the Environment
5480.4	Environmental Protection, Safety, and Health Protection Standards
5480.19	Conduct of Operations Requirements for DOE Facilities
5480.20A	Personnel Selection Qualifications, Training, and Staffing Requirements at DOE Reactor and Nonreactor Nuclear Facilities
5480.21	Unreviewed Safety Questions
5480.22	Technical Safety Requirements
5480.23	Nuclear Safety Analysis Reports
5482.1B	Environment, Safety, and Health Appraisal Program
5484.1	Environmental Protection, Safety, and Health Protection Information Reporting Requirements
5530.1A	Accident Response Group
5530.3	Radiological Assistance Program
5530.4	Aerial Measuring System
5530.5	Federal Radiological Monitoring and Assessment Center
5630.12A	Safeguards and Security Inspection and Assessment Program
5630.13	Master Safeguards and Security Agreements
5632.1C	Protection and Control of Safeguards and Security Interests
5633.3B	Control and Accountability of Nuclear Materials
5700.6C	Quality Assurance
5820.2A	Radioactive Waste Management

Table J–4. Applicable Nuclear Regulatory Commission Guidelines

Guide Number	Title	Latest Rev. Date
3.3	Quality Assurance Program Requirements for Fuel Reprocessing Plants and for Plutonium Processing and Fuel Fabrication Plants	3/74
3.7	Monitoring of Combustible Gases and Vapors in Plutonium Processing and Fuel Fabrication Plants	3/73
3.10	Liquid Waste Treatment System Design Guide for Plutonium Processing and Fuel Fabrication Plants	6/73
3.12	General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants	8/73
3.14	Seismic Design Classification for Plutonium Processing and Fuel Fabrication Plants	10/73
3.16	General Fire Protection Guide for Plutonium Processing and Fuel Fabrication Plants	1/74
3.21	Quality Assurance Requirements for Protective Coatings Applied to Fuel Reprocessing and to Plutonium Processing and Fuel Fabrication Plants	3/74
3.28	Welder Qualifications for Welding in Areas of Limited Accessibility in Fuel Reprocessing and in Plutonium Processing and Fuel Fabrication Plants	5/75
3.29	Preheat and Interpass Temperature Control for the Welding of Low-Alloy Steel for Use in Fuel Reprocessing Plants and in Plutonium Processing and Fuel Fabrication Plants	5/75
3.35	Assumptions Used for Evaluating the Potential Radiological Consequences of Accidental Nuclear Criticality in a Plutonium Processing and Fuel Fabrication Plant	7/79
3.39	Standard Format and Content of License Applications for Plutonium Processing and Fuel Fabrication Plants	1/76
3.40	Design Basis Floods for Fuel Reprocessing Plants and for Plutonium Processing and Fuel Fabrication Plants	12/72
3.47	Nuclear Criticality Control and Safety of Homogeneous Plutonium-Uranium Fuel Mixtures Outside Reactors	7/81

Appendix K
Biological Resources

Table K–1 contains a listing of the scientific names of common, nonthreatened, and nonendangered animal and plant species found in Chapters 3 and 4. Species are grouped and listed in alphabetical order by common name.

Table K–1. Scientific Names of Nonthreatened and Nonendangered Animal and Plant Species Referred to in the Text

Common Name	Scientific Name
Mammals	
Abert's squirrel	*Sciurus aberti*
Badger	*Taxidea taxus*
Beaver	*Castor canadensis*
Bighorn sheep	*Ovis canadensis*
Black bear	*Ursus americanus*
Black-footed ferret	*Mustela nigripes*
Black-tailed jackrabbit	*Lepus californicus*
Black-tailed prairie dog	*Cynomys ludovicianus*
Bobcat	*Lynx rufus*
[Text deleted.]	
Cactus mouse	*Peromyscus eremicus*
Coyote	*Canis latrans*
Deer mouse	*Peromyscus maniculatus*
Desert cottontail	*Sylvilagus auduboni*
Eastern cottontail	*Sylvilagus floridanus*
Eastern gray squirrel	*Sciurus carolinensis*
Elk	*Cervus elaphus*
Feral hog	*Sus scrofa*
Gray fox	*Urocyon cinereoargenteus*
Great Basin kangaroo rat	*Dipodomys microps*
Great Basin pocket mouse	*Perognathus parvus*
Hispid cotton rat	*Sigmodon hispidus*
Javelina	*Pecari angulatus*
Long-tailed weasel	*Mustela frenata*
Merriam's kangaroo rat	*Dipodomys merriami*
Mexican woodrat	*Neotoma mexicana*
Mink	*Mustela vison*
Moose	*Alces alces*
Mountain cottontail	*Sylvilagus nuttalli*
Mountain lion	*Felis concolor*
Mule deer	*Odocoileus hemionus*
Opossum	*Didelphis marsupialis*
[Text deleted.]	
Porcupine	*Erethizon dorsatum*
Pronghorn	*Antilocapra americana*
Raccoon	*Procyon lotor*
Red squirrel	*Tamiasciurus hudsonicus*
Round-tailed ground squirrel	*Spermophilus tereticaudus*
Snowshoe hare	*Lepus americanus*
Thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*
Townsend's ground squirrel	*Spermophilus townsendii*
White-footed mouse	*Peromyscus leucopus*
Whitetail deer	*Odocoileus virginianus*
Birds	
[Text deleted.]	
American kestrel	*Falco sparverius*
American robin	*Turdus migratorius*
Black vulture	*Coragyps atratus*
Black-throated sparrow	*Amphispiza bilineata*
Boreal chickadee	*Parus hudsonicus*
[Text deleted.]	
Canada goose	*Branta canadensis*
Carolina chickadee	*Parus carolinensis*
Common crow	*Corvus brachyrhynchos*
Common raven	*Corvus corax*
Downy woodpecker	*Picoides pubescens*
Eastern bluebird	*Sialia sialis*
Forster's tern	*Sterna forsteri*
Gambel's quail	*Callipepla gambelii*
Great blue heron	*Ardea herodias*
[Text deleted.]	
Great horned owl	*Bubo virginianus*
Greater prairie chicken	*Tympanuchus cupido*
Greater roadrunner	*Geococcyx californianus*
Horned lark	*Eremophila alpestris*
House finch	*Carduelis mexicanus*
Lesser goldfinch	*Carduelis psaltria*
Magpie	*Pica spp.*
Mourning dove	*Zenaida macroura*
Nighthawk	*Chordeiles spp.*
Northern bobwhite	*Colinus virginianus*
Northern cardinal	*Cardinalis cardinalis*
[Text deleted.]	
Northern harrier	*Circus cyaneus*
Ovenbird	*Seiurus aurocapillus*
Pelican	*Pelecanus spp.*
Pine siskin	*Carduelis pinus*
Raven	*Corvus spp.*
Red crossbill	*Loxia curvirostra*
Red-breasted nuthatch	*Sitta canadensis*
Red-tailed hawk	*Buteo jamaicensis*
Ring-billed gull	*Larus delawarensis*
Ring-necked pheasant	*Phasianus colchicus*
Rough-legged hawk	*Buteo lagopus*
Ruffed grouse	*Bonasa umbellus*
Sage grouse	*Centrocercus urophasianus*
Say's phoebe	*Sayornis saya*
Scaled quail	*Callipepla squamata*
Scrub jay	*Aphelocoma coerulescens*
Turkey vulture	*Cathartes aura*
Western meadowlark	*Sturnella neglecta*
Wild turkey	*Meleagris gallopavo*
Wood thrush	*Hylocichla mustelina*

Table K–1. Scientific Names of Nonthreatened and Nonendangered Animal and Plant Species Referred to in the Text—Continued

Common Name	Scientific Name
Worm-eating warbler	*Helmitheros vermivorus*
[Text deleted.]	
Reptiles	
Banded gecko	*Coleonyx variegatus*
[Text deleted.]	
Collared lizard	*Crotaphytus collaris*
Common bullsnake	*Pitriophis melanoleucus*
Common garter snake	*Thamnophis sirtalis*
[Text deleted.]	
Desert iguana	*Dipsosaurus dorsalis*
Eastern box turtle	*Terrapene carolina*
Eastern diamondback rattlesnake	*Crotalus adamanteus*
Eastern fence lizard	*Sceloporus undulatus*
Eastern garter snake	*Thamnophis sirtalis*
Eastern ribbon snake	*Thamnophis sauritus*
Gopher snake	*Pituophis melanoleucus*
[Text deleted.]	
Painted turtle	*Chrysemys picta*
Prairie kingsnake	*Lampropeltis calligaster*
Prairie rattlesnake	*Crotalus viridis*
Rat snake	*Elaphe obsoleta*
Ring-necked snake	*Diadophis punctatus*
Sagebrush lizard	*Sciloporus graciosus*
Short-horned lizard	*Phyrnosoma douglassi*
Side-blotched lizard	*Uta stansburiana*
Smooth green snake	*Opheodrys vernalis*
Western box turtle	*Terrapene ornata*
[Text deleted.]	
Western shovel-nosed snake	*Chionactis occipitalis*
Western skink	*Eumeces skeltonianus*
Whiptail lizard	*Cnemidophorus spp.*

Common Name	Scientific Name
Amphibians	
American toad	*Bufo americanus*
[Text deleted.]	
Chorus frog	*Pseudacris triseriata*
[Text deleted.]	
Great Plains toad	*Bufo cognatus*
[Text deleted.]	
Green frog	*Rana clamitans*
[Text deleted.]	
Pine woods treefrog	*Hyla femoralis*
Slimy salamander	*Plethodon glutinosus*
Spotted salamander	*Ambystoma maculatum*
Fish	
American shad	*Alosa sapidissima*
Banded sculpin	*Cottus carolinae*
Black crappie	*Pomoxis nigromaculatus*
Blacknose dace	*Rhinichthys atratulus*
Blueback herring	*Alosa aestivalis*
Bluegill	*Lepomis macrochirus*
Bluntnose minnow	*Pimephales notatus*
Bream	*Lepomis spp.*
Brook trout	*Salvelinus fontinalis*
Brown trout	*Salmo trutta*
Carpsucker	*Carpiodes spp.*
Central stoneroller	*Campostoma anomalum*
Channel catfish	*Ictalurus punctatus*
Chinook salmon	*Oncorhynchus tshawytscho*
Chub	*Cyprinidae*
Coho salmon	*Oncorhynchus kisutch*
Common carp	*Cyprinus carpio*
Crappie	*Pomoxis spp.*
Creek chub	*Semotilus atromaculatus*

Common Name	Scientific Name
Fathead minnow	*Pimephales promelas*
Freshwater drum	*Aplodinotus grunniens*
Golden shiner	*Notemigonus crysoleucas*
Goldfish	*Carassius auratus*
Green sunfish	*Lepomis cyanellus*
Hickory shad	*Alosa mediocris*
Kokanee salmon	*Oncorhynchus nerka*
Lake chubsucker	*Erimyzon sucetta*
Largemouth bass	*Micropterus salmoides*
Mosquitofish	*Gambusia affinis*
Mountain whitefish	*Prosopium williamsoni*
Mud sunfish	*Acantharchus pomotis*
Pickerel	*Esox spp.*
Rainbow trout	*Oncorhynchus mykiss*
Redbreast sunfish	*Lepomis auritus*
Redfin pickerel	*Esox americanus*
Redside dace	*Clinostomus elongatus*
Rock bass	*Ambloplites rupestris*
Sauger	*Stizostedion canadense*
Shorthead sculpin	*Cottus confusus*
Smallmouth bass	*Micropterus dolomieu*
Sockeye salmon	*Oncorhynchus nerka*
Speckled dace	*Rhinichthys osculus*
Steelhead trout	*Oncorhynchus mykiss*
Striped bass	*Morone saxatilis*
Sunfish	*Lepomis spp.*
Walleye	*Stizostedion vitreum*
White sturgeon	*Acipenser transmontanus*
White sucker	*Catostomus commersoni*
Plants	
American elm	*Ulmus americana*
American watercress	*Barbarea orthoceras*
Aspen	*Populus spp.*

Table K–1. Scientific Names of Nonthreatened and Nonendangered Animal and Plant Species Referred to in the Text—Continued

Common Name	Scientific Name
Bald cypress	*Taxodium distichum*
Balsam fir	*Abies balsamea*
Basswood	*Tilia americana*
Beech	*Fagus spp.*
Big sagebrush	*Artemisia tridentata*
Blackbrush	*Coleogyne ramosissima*
Blue grama	*Bouteloua gracilis*
Bluebunch wheatgrass	*Agropyron spicatum*
Bottlebrush squirreltail	*Sitanion hystrix*
Broadleaf cattail	*Typha latifolia*
Buffalo-grass	*Buchloe dactyloides*
Bulrush	*Scirpus spp.*
Canada bluegrass	*Poa canbyi*
Cattail	*Typha spp.*
Cedar	*Juniperus virginiana*
Cheatgrass	*Bromus tectorum*
Cholla	*Opuntia sp.*
Cottonwood	*Populus spp.*
Creosote bush	*Larrea tridentata*
Crested wheatgrass	*Agropyron desertorum*
Desert thorn	*Lycium pallidum*
Desert thorn	*Lycium shockleyi*
Douglas fir	*Pseudotsuga menziesii*
Fir	*Abies sp.*
Giant wildrye	*Elymus condensatus*
Gray horsebrush	*Tetradymia canescens*
Gray rabbitbrush	*Chrysothamnus nauseous*
Greasewood	*Sarcobatus vermiculatus*
Green rabbitbrush	*Chrysothamnus greenei*
Hemlock	*Tsuga canadensis*
Hickory	*Carya spp.*
Hopsage	*Grayia spinosa*
Indian ricegrass	*Oryzopsis hymenoides*
Juniper	*Juniperus spp.*
Little bluestem	*Schizachyrium scoparium*
Loblolly pine	*Pinus taeda*
Longleaf pine	*Pinus palustris*
Low sagebrush	*Artemisia arbuscula*
Maple	*Acer spp.*
Needle-and-thread grass	*Stipa comata*
Oak	*Quercus spp.*
One-seed juniper	*Juniperus monosperma*
Paper birch	*Betula papyrifera*
Peachleaf willow	*Salix amygdaloides*
Pine	*Pinus spp.*
Pinyon pine	*Pinus edulis*
Pitch pine	*Pinus rigida*
Plains cottonwood	*Populus sargentii*
Ponderosa pine	*Pinus ponderosa*
[Text deleted.]	
Poplar	*Populus spp.*
Poverty-weed	*Monolepis nuttaliana*
Prickly pear cactus	*Opuntia spp.*
Rabbitbrush	*Chrysothamnus spp.*
Red brome	*Bromus rubens*
Red oak	*Quercus rubra*
Red spruce	*Picea rubens*
[Text deleted.]	
Rush	*Juncus spp.*
Russian thisle	*Salsola kali*
Sagebrush	*Artemisia spp.*
Saltbush	*Atriplex spp.*
Sandbar willow	*Salix interior*
Sandberg's bluegrass	*Poa sandbergii*
Shortleaf pine	*Pinus echinata*
Sideoats grama	*Bouteloua curtipendula*
Slash pine	*Pinus elliottii*
Snowy buckwheat	*Eriogonum niveum*
Spike rush	*Eleocharis spp.*
Spiny hopsage	*Grayia spinosa*
Sweet gum	*Liguidambar styraciflua*
Thickspike wheatgrass	*Agropyron dasytachyum*
Threetip sagebrush	*Artemisia tripartita*
Thyme buckwheat	*Eriogonum thymoides*
Tumble mustard	*Sisymbrium altissimum*
Tupelo	*Nyssa slyvotica*
Utah juniper	*Juniperus osteosperma*
Virginia pine	*Pinus virginiana*
Watercress	*Rorippa nasturtium-aquaticum*
[Text deleted.]	
Western wheatgrass	*Agropyron smithii*
White ash	*Fraxinus americanum*
White pine	*Pinus strobus*
Willow	*Salix spp.*
Winterfat	*Eurotia lanata*

Appendix L
Socioeconomics

L.1 INTRODUCTION

Appendix L includes the supporting data used for assessing the No Action Alternative in the socioeconomics sections of this programmatic environmental impact statement. The socioeconomic analysis involved two major steps: (1) the characterization and projection of existing social, economic, and infrastructure conditions surrounding each of the candidate sites (that is, the affected environment); and (2) the evaluation of potential changes in socioeconomic conditions that could result from alternatives in the regions addressed (that is, the environmental consequences). Data and analyses used to support the assessment made for the socioeconomic sections for the No Action Alternative are presented in Tables L.1–1 to L.1–90. Data and analyses used to support the assessment of potential impacts as a result of project alternatives are contained in a separate report (Socio 1996a).

The socioeconomic environment is defined for two geographic regions: the regional economic area (REA) and the region of influence (ROI). REAs are used to assess potential effects on the regional economy, and ROIs are used to assess effects that are more localized in political jurisdictions surrounding the sites.

The REA for each site encompasses a broad market that involves trade among and between regional industrial and service sectors and is characterized by strong economic linkages between the communities in the region. These linkages determine the nature and magnitude of multiplier effects of economic activity (purchases, earnings, and employment) at each site. REAs are defined by the U.S. Bureau of Economic Analysis and consist of an economic node that serves as the center of economic activity, and the surrounding counties that are economically related and include the places of work and residences of the labor force.

Potential demographic impacts were assessed for each ROI, a smaller geographic area where the housing market and local community services would be most affected. Site-specific ROIs were identified as those counties where approximately 90 percent of the current Department of Energy and/or contractor employees reside. This residential distribution reflects existing commuting patterns and attractiveness of area communities for people employed at each site and is used to estimate the future distribution of in-migrating workers.

Table L.1–1. Department of Energy Sites' Regional Economic Areas by County

Hanford	NTS	INEL	Pantex		ORR	SRS	RFETS			LANL
Washington	**Arizona**	**Idaho**	**New Mexico**	**Texas (cont'd)**	**Tennessee**	**Georgia**	**Colorado**	**Colorado**	**Kansas**	**New Mexico**
Adams	Mohave	Bannock	Curry	Hall	Anderson	Burke	Adams	**(cont'd)**	Cheyenne	Guadalupe
Benton		Bingham	DeBaca	Hansford	Blount	Columbia	Arapahoe	Kit Carson	Gove	Mora
Chelan		Bonneville	Harding	Hartley	Campbell	Glascock	Boulder	Lake	Logan	Taos
Douglas	**Nevada**	Butte	Quay	Hemphill	Cocke	Jefferson	Chaffee	Larimer	Sheridan	San Miguel
Franklin	Clark	Clark	Roosevelt	Hutchinson	Grainger	Jenkins	Clear Creek	Lincoln	Sherman	Los Alamos
Grant	Esmeralda	Custer	Union	Lipscomb	Hamblen	Lincoln	Custer	Logan	Thomas	Santa Fe
Kittitas	Lincoln	Fremont		Moore	Hancock	McDuffie	Delta	Mesa	Wallace	Rio Arriba
Okanogan	Mineral	Jefferson		Ochiltree	Jefferson	Richmond	Denver	Moffat		
Yakima	Nye	Lemhi	**Texas**	Oldham	Knox	Warren	Douglas	Montrose		
		Madison	Armstrong	Parmer	Loudon	Wilkes	Eagle	Morgan	**Nebraska**	
		Power	Bailey	Potter	Morgan		El Paso	Ouray	Dundy	
	Utah	Teton	Carson	Randall	Roane		Elbert	Park		
	Beaver		Castro	Roberts	Scott	**South Carolina**	Fremont	Phillips		
	Garfield		Childress	Sherman	Sevier	Aiken	Garfield	Pitkin		
	Iron	**Wyoming**	Collingsworth	Wheeler	Union	Allendale	Gilpin	Rio Blanco		
	Piute	Teton	Cottle			Bamberg	Grand	Routt		
	Washington		Dallam			Barnwell	Gunnison	San Miguel		
			Deaf Smith			Edgefield	Hinsdale	Summit		
			Donley				Jackson	Teller		
			Gray				Jefferson	Washington		
								Weld		
								Yuma		

Source: DOC 1995a.

Table L.1–2. Distribution of Employees by Place of Residence in the Hanford Site Region of Influence, 1996

County/City	Number of Employees	Total Site Employment (percent)
Benton County	11,494	78.8
Kennewick	4,230	29.0
Richland	5,295	36.3
West Richland	1,109	7.6
Franklin County	1,298	8.9
Pasco	1,284	8.8
Yakima County	452	3.1
[Text deleted.]		
ROI Total	13,244	90.8

Note: City values are included within county totals.

Source: HF 1996a:2.

Table L.1–3. Distribution of Employees by Place of Residence in the Nevada Test Site Region of Influence, 1991

County/City	Number of Employees	Total Site Employment (percent)
Clark County	6,270	81.7
Henderson	357	4.7
Las Vegas	5,352	69.7
North Las Vegas	505	6.6
Nye County	1,173	15.3
ROI Total	7,443	97.0

Note: City values are included within county totals.

Source: NTS 1991a:1.

Table L.1–4. Distribution of Employees by Place of Residence in the Idaho National Engineering Laboratory Region of Influence, 1991

County/City	Number of Employees	Total Site Employment (percent)
Bannock County	342	5.3
Pocatello	317	4.9
Bingham County	576	8.9
Blackfoot	460	7.1
Bonneville County	4,893	75.7
Idaho Falls	4,750	73.5
Butte County	123	1.9
Jefferson County	419	6.5
Rigby	320	4.9
ROI Total	6,353	98.3

Note: City values are included within county totals. Employees do not include Westinghouse or ICPP. The percent of employees residing in each city and county in this table were used to analyze socioeconomic effects. These percentages differ from the updated percentages shown in paragraph 3.4.8 which did not include city data. City data is required to conduct the socioeconomic analysis.

Source: INEL 1991a:6.

Table L.1–5. Distribution of Employees by Place of Residence in the Pantex Plant Region of Influence, 1994

County/City	Number of Employees	Total Site Employment (percent)
Armstrong County	51	1.4
Carson County	191	5.4
Potter County	1,224	34.4
Amarillo	3,030	85.1
Randall County	1,943	54.6
ROI Total	3,409	95.8

Note: City values are included within county totals. Potter and Randall Counties each reflect a part of Amarillo.
Source: PX 1994a:2.

Table L.1–6. Distribution of Employees by Place of Residence in the Oak Ridge Reservation Region of Influence, 1990

County/City	Number of Employees	Total Site Employment (percent)
Anderson County	5,053	33.1
Clinton	1,035	6.8
Oak Ridge	3,292	21.6
Knox County	5,490	36.0
Knoxville	4,835	31.7
Loudon County	848	5.6
Lenoir City	638	4.2
Roane County	2,537	16.6
Harriman	802	5.3
Kingston	1,033	6.8
ROI Total	13,928	91.3

Note: City values are included within county totals.
Source: ORR 1991a:4.

Table L.1–7. Distribution of Employees by Place of Residence in the Savannah River Site Region of Influence, 1991

County/City	Number of Employees	Total Site Employment (percent)
Aiken County	9,978	51.9
Aiken	4,928	25.7
North Augusta	2,666	13.9
Allendale County	217	1.1
Bamberg County	329	1.7
Barnwell County	1,401	7.3
Columbia County	2,036	10.6
Richmond County	3,358	17.5
Augusta	2,780	14.5
ROI Total	17,319	90.1

Note: City values are included within county totals.
Source: SRS 1991a:3.

Table L.1–8. Distribution of Employees by Place of Residence in the Rocky Flats Environmental Technology Site Region of Influence, 1995

County/City	Number of Employees	Total Site Employment (percent)
Adams County	887	20.0
Westminster	637	14.4
Thornton	230	5.2
Arapahoe County	158	3.6
Boulder County	1,135	25.6
Broomfield	373	8.4
Longmont	227	5.1
Denver County	276	6.2
Jefferson County	1,559	35.2
Arvada	659	14.9
ROI Total	4,015	90.6

Note: City values are included within county totals.
Source: RFETS 1995a:1.

Table L.1–9. Distribution of Employees by Place of Residence in the Los Alamos National Laboratory Region of Influence, 1991

County/City	Number of Employees	Total Site Employment (percent)
Los Alamos County	4,697	48.3
Rio Arriba County	2,027	20.8
Espanola	944	9.7
Santa Fe County	1,851	19.0
Santa Fe	1,548	15.9
ROI Total	8,575	88.1

Note: City values are included within county totals.
Source: LANL 1991b:6.

Table L.1–10. Hanford Site Regional Economic Area Employment and Economy, 1995-2040

Regional Economic Area	1995	2000	2005	2010	2015	2020	2030	2040
Civilian labor force	332,000	354,100	373,700	392,200	411,200	428,300	458,500	490,700
Total employment	301,900	322,000	339,800	356,600	374,000	389,500	416,000	446,300
Unemployment rate (percent)	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Total personal income (thousands of dollars)	11,577,987	13,168,249	14,667,279	16,157,208	17,766,227	19,272,231	22,080,020	25,296,940
Per capita income (dollars)	18,996	20,259	21,381	22,441	23,531	24,508	26,233	28,079

Source: Census 1993k; Census 1994o; Census 1995a; DOC 1994j; DOC 1995a; DOC 1996a; DOC 1996b; DOL 1991a; DOL 1995a.

Table L.1–11. Hanford Site Region of Influence Population, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Benton County	131,00	139,700	147,400	154,700	161,700	169,000	180,900	193,600
Kennewick	48,700	52,000	54,800	57,600	60,200	62,900	67,300	72,000
Richland	36,200	38,600	40,700	42,800	44,700	46,700	50,000	53,500
West Richland	5,900	6,300	6,700	7,000	7,300	7,600	8,200	8,700
Franklin County	43,300	46,100	48,700	51,100	53,400	55,800	59,700	64,000
Pasco	23,500	25,100	26,500	27,800	29,000	30,400	32,500	34,800
Yakima County	210,400	224,400	236,800	248,500	259,700	271,400	290,500	311,000
[Text deleted.]								
ROI Total	384,700	410,200	432,900	454,300	474,800	496,200	531,100	568,600

Note: City values are included within county totals.
Source: Census 1993k; Census 1994o; Census 1995a; DOC 1994j; DOC 1996a; DOC 1996b.

Table L.1–12. Hanford Site Region of Influence Total Number of Owner and Renter Housing Units, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Benton County	50,400	53,800	56,700	59,600	62,200	65,000	69,600	74,500
Kennewick	19,200	20,400	21,600	22,600	23,600	24,700	26,500	28,300
Richland	15,100	16,100	17,000	17,800	18,600	19,500	20,800	22,300
West Richland	2,200	2,400	2,500	2,700	2,800	2,900	3,100	3,300
Franklin County	14,800	15,700	16,600	17,400	18,200	19,100	20,400	21,800
Pasco	8,500	9,000	9,500	10,000	10,400	10,900	11,700	12,500
Yakima County	75,700	80,800	85,200	89,400	93,500	97,700	104,600	111,900
[Text deleted.]								
ROI Total	140,900	150,300	158,500	166,400	173,900	181,800	194,600	208,200

Note: City values are included within county totals.
Source: Census 1991d; Table L.1–11.

Table L.1–13. Hanford Site Region of Influence Total Student Enrollment, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Benton County	25,494	27,198	28,702	30,115	31,489	32,882	35,198	37,674
Finley District	1,130	1,210	1,280	1,340	1,400	1,460	1,560	1,670
Kennewick District	12,340	13,160	13,880	14,570	15,230	15,910	17,030	18,230
Kiona Benton District	1,410	1,510	1,590	1,670	1,750	1,820	1,950	2,090
Patterson District	64	68	72	75	79	82	88	94
Prosser District	2,590	2,760	2,920	3,060	3,200	3,340	3,580	3,830
Richland District	7,960	8,490	8,960	9,400	9,830	10,270	10,990	11,760
Franklin County	8,927	9,524	10,049	10,550	11,031	11,522	12,324	13,195
Kahlotus District	90	96	100	110	110	120	120	130
North Franklin District	1,760	1,880	1,980	2,080	2,180	2,270	2,430	2,610
Pasco District	7,060	7,530	7,950	8,340	8,720	9,110	9,750	10,430
Star District	17	18	19	20	21	22	24	25
Yakima County	42,470	45,310	47,800	50,180	52,430	54,790	58,630	62,790
East Valley District	2,110	2,250	2,370	2,490	2,600	2,720	2,910	3,120
Grandview District	2,630	2,810	2,960	3,110	3,250	3,390	3,630	3,890
Granger District	1,100	1,180	1,240	1,310	1,360	1,420	1,520	1,630
Highland District	1,010	1,080	1,140	1,190	1,250	1,300	1,400	1,490
Mabton District	800	850	900	940	990	1,030	1,110	1,180
Mount Adams District	1,110	1,180	1,250	1,310	1,370	1,430	1,530	1,640
Naches Valley District	1,390	1,490	1,570	1,650	1,720	1,800	1,920	2,060
Selah District	3,350	3,570	3,770	3,960	4,130	4,320	4,620	4,950
Sunnyside District	4,520	4,820	5,090	5,340	5,580	5,840	6,250	6,690
Toppenish District	2,980	3,180	3,350	3,520	3,680	3,840	4,110	4,400
Union Gap District	480	520	550	570	600	630	670	720
Wapato District	3,090	3,290	3,470	3,650	3,810	3,980	4,260	4,560
West Valley District	4,130	4,400	4,640	4,870	5,090	5,320	5,700	6,100
Yakima District	12,700	13,540	14,290	15,000	15,670	16,380	17,530	18,770
Zillah District	1,070	1,150	1,210	1,270	1,330	1,390	1,480	1,590
ROI Total	76,891	82,032	86,551	90,845	94,950	99,194	106,152	113,659

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–11.

Table L.1–14. Hanford Site Region of Influence Total Number of Teachers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Benton County	1,303	1,388	1,467	1,540	1,607	1,680	1,800	1,925
Finley District	57	60	64	67	70	73	78	84
Kennewick District	647	690	729	765	799	835	894	957
Kiona Benton District	66	70	74	78	85	90	91	92
Patterson District	4	4	5	5	5	5	6	6
Prosser District	139	148	156	164	171	179	192	205
Richland District	390	416	439	461	481	503	539	576
Franklin County	527	563	593	623	653	682	729	780
Kahlotus District	15	16	17	18	19	20	21	22
North Franklin District	95	102	107	112	118	123	131	141
Pasco District	415	443	467	491	513	537	574	614
Star District	2	2	2	2	3	3	3	3
Yakima County	2,247	2,396	2,527	2,654	2,773	2,897	3,102	3,318
East Valley District	110	118	124	130	136	142	152	163
Grandview District	133	142	149	157	164	171	183	196
Granger District	57	61	64	67	70	73	78	84
Highland District	54	57	60	63	66	69	74	79
Mabton District	45	48	50	53	55	57	62	66
Mount Adams District	60	64	67	71	74	77	83	88
Naches Valley District	69	73	78	81	85	89	95	102
Selah District	173	185	195	205	214	223	239	256
Sunnyside District	230	245	259	272	284	297	318	340
Toppenish District	163	174	184	193	201	210	225	241
Union Gap District	27	29	31	32	34	35	38	40
Wapato District	153	163	172	181	189	197	211	226
West Valley District	205	218	230	242	253	264	283	302
Yakima District	716	763	805	845	883	923	988	1,057
Zillah District	53	56	59	62	65	68	73	78
ROI Total	4,077	4,347	4,587	4,817	5,033	5,259	5,631	6,023

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–11.

Table L.1–15. Hanford Site Region of Influence Total Number of Sworn Police Officers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Benton County	57	60	64	67	70	73	78	84
Kennewick	67	71	75	79	83	86	92	99
Richland	45	48	50	53	55	58	62	66
West Richland	10	11	11	12	13	13	14	15
Franklin County	21	23	24	25	26	27	29	31
Pasco	44	46	49	51	54	56	60	64
Yakima County	259	277	292	306	320	335	358	383
[Text deleted.]								
ROI Total	503	536	565	593	621	648	693	742

Note: Non-ROI cities included in county number.
Source: DOJ 1995a; Table L.1–11.

Table L.1–16. Hanford Site Region of Influence Total Number of Firefighters, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Benton County	251	268	283	297	310	324	347	371
Kennewick	58	62	65	68	71	74	80	85
Richland	46	49	51	54	56	59	63	67
West Richland	32	35	36	38	40	42	45	48
Franklin County	152	162	171	179	188	196	210	225
Pasco	84	90	95	99	104	108	116	124
Yakima County	921	982	1,036	1,088	1,137	1,188	1,272	1,361
[Text deleted.]								
ROI Total	1,544	1,648	1,737	1,823	1,906	1,991	2,133	2,281

Note: Non-ROI cities included in county number.
Source: Socio 1996a; Table L.1–11.

Table L.1–17. Hanford Site Region of Influence Hospital Occupancy Rates, 1995-2040

County/City	1995 (percent)	2000 (percent)	2005 (percent)	2010 (percent)	2015 (percent)	2020 (percent)	2030 (percent)	2040 (percent)
Benton County	48	52	54	57	60	62	67	71
Franklin County	48	51	54	56	59	61	66	70
Yakima County	53	57	60	63	68	72	72	73
ROI Average	51	54	57	60	63	66	70	75

Source: AHA 1995a; Table L.1–11.

Table L.1–18. Hanford Site Region of Influence Total Number of Doctors, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Benton County	151	161	170	178	186	195	208	223
Franklin County	42	44	47	49	51	54	57	61
Yakima County	279	297	314	329	344	359	385	412
ROI Total	472	502	531	556	581	608	650	696

Source: AMA 1995a; Table L.1–11.

Table L.1–19. Nevada Test Site Regional Economic Area Employment and Economy, 1995-2040

Regional Economic Area	1995	2000	2005	2010	2015	2020	2030	2040
Civilian labor force	625,300	731,600	822,700	910,100	991,200	1,063,900	1,183,800	1,317,200
Total employment	587,000	686,800	772,300	854,400	930,500	998,700	1,111,300	1,236,600
Unemployment rate (percent)	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
Total personal income (thousands of dollars)	26,000,837	35,588,677	45,005,896	55,080,114	65,335,105	75,263,852	93,188,103	115,381,024
Per capita income (dollars)	21,900	25,622	28,813	31,875	34,716	37,260	41,460	46,134

Source: Census 1993f; Census 1993y; Census 1993z; Census 1994o; Census 1995a; DOC 1994j; DOC 1995a; DOC 1996a; DOC 1996b; DOL 1991a; DOL 1995a.

Table L.1–20. Nevada Test Site Region of Influence Population, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Clark County	968,100	1,132,700	1,273,700	1,409,100	1,523,500	1,647,200	1,832,900	2,039,500
Henderson	105,200	123,100	138,500	153,200	165,600	179,100	199,300	221,700
Las Vegas	338,300	395,800	445,100	492,400	532,400	575,600	640,500	712,700
North Las Vegas	66,600	77,900	87,600	96,600	104,800	113,300	126,100	140,300
Nye County	22,600	26,400	29,700	32,800	35,500	38,400	42,700	47,500
ROI Total	990,700	1,159,100	1,303,400	1,441,900	1,559,000	1,685,600	1,875,600	2,087,000

Note: City values are included within county totals.

Source: Census 1993y; Census 1994o; Census 1995a; DOC 1994j; DOC 1996a; DOC 1996b.

Table L.1–21. Nevada Test Site Region of Influence Total Number of Owner and Renter Housing Units, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Clark County	394,800	461,800	519,400	574,600	621,200	671,600	747,300	831,600
Henderson	40,000	46,800	52,700	58,300	63,000	68,100	75,800	84,300
Las Vegas	140,300	164,200	184,600	204,300	220,800	238,800	265,700	295,700
North Las Vegas	21,400	25,000	28,100	31,000	33,600	36,300	40,400	45,000
Nye County	8,900	10,500	11,800	13,000	14,100	15,200	16,900	18,900
ROI Total	403,700	472,300	531,200	587,600	635,300	686,800	764,200	850,500

Note: City values are included within county totals.

Source: Census 1991g; Table L.1–20.

Table L.1–22. Nevada Test Site Region of Influence Total Student Enrollment, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Clark County	161,330	188,750	212,260	234,820	253,880	274,490	305,430	339,860
Nye County	4,300	5,030	5,660	6,260	6,770	7,320	8,150	9,060
ROI Total	165,630	193,780	217,920	241,080	260,650	281,810	313,580	348,920

Source: Socio 1996a; Table L.1–20.

Table L.1–23. Nevada Test Site Region of Influence Total Number of Teachers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Clark County	8,217	9,613	10,811	11,960	12,930	13,980	15,556	17,309
Nye County	249	291	327	362	391	423	471	524
ROI Total	8,466	9,904	11,138	12,322	13,321	14,403	16,027	17,833

Source: Socio 1996a; Table L.1–20.

Table L.1–24. Nevada Test Site Region of Influence Total Number of Sworn Police Officers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Clark County	23	27	30	33	36	39	43	48
Henderson	158	185	208	230	248	269	299	333
Las Vegas	1,561	1,827	2,054	2,273	2,457	2,656	2,956	3,289
North Las Vegas	130	152	171	189	205	221	246	274
[Text deleted.]								
Nye County	74	87	98	108	117	126	141	157
ROI Total	1,946	2,278	2,561	2,833	3,063	3,311	3,685	4,101

Note: Incorporated cities in Clark County provide police protection. Non-ROI cities included within county number. Las Vegas Police Department also serves unincorporated Clark County.

Source: DOJ 1995a; Table L.1–20.

Table L.1–25. Nevada Test Site Region of Influence Total Number of Firefighters, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Clark County	925	1,082	1,216	1,347	1,455	1,573	1,750	1,948
Henderson	90	105	118	131	141	153	170	189
Las Vegas	330	386	434	481	520	562	625	696
North Las Vegas	71	83	94	103	112	121	135	150
Nye County	137	161	181	200	216	233	260	289
ROI Total	1,553	1,817	2,043	2,262	2,444	2,642	2,940	3,271

Note: Non-ROI cities are included within county number.
Source: Socio 1996a; Table L.1–20.

Table L.1–26. Nevada Test Site Region of Influence Hospital Occupancy Rates, 1995-2040

County/City	1995 (percent)	2000 (percent)	2005 (percent)	2010 (percent)	2015 (percent)	2020 (percent)	2030 (percent)	2040 (percent)
Clark County	63	74	83	92	99	107	119	133
Nye County	34	40	45	50	54	59	65	73
ROI Average	62	73	82	91	98	106	118	131

Source: AHA 1995a; Table L.1–20.

Table L.1–27. Nevada Test Site Region of Influence Total Number of Doctors, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Clark County	1,283	1,501	1,689	1,858	2,009	2,172	2,417	2,689
Nye County	7	8	10	11	11	12	14	15
ROI Total	1,276	1,493	1,679	1,869	2,020	2,184	2,431	2,704

Source: AMA 1995a; Table L.1–20.

Table L.1–28. Idaho National Engineering Laboratory Regional Economic Area Employment and Economy, 1995-2040

Regional Economic Area	1995	2000	2005	2010	2015	2020	2030	2040
Civilian labor force	151,400	161,300	168,100	174,400	181,200	188,200	200,700	214,000
Total employment	143,300	152,600	159,100	165,000	171,500	178,100	189,900	202,500
Unemployment rate (%)	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Total personal income (thousands of dollars)	4,928,397	5,592,534	6,076,196	6,540,456	7,062,688	7,615,420	8,661,350	9,850,930
Per capita income (dollars)	17,701	18,217	18,988	19,700	20,472	21,258	22,670	24,177

Source: Census 1993n; Census 1993o; Census 1995a; DOC 1994j; DOC 1995a; DOC 1996a; DOC 1996b; DOL 1991a; DOL 1995a; INEL 1995a:1.

Table L.1–29. Idaho National Engineering Laboratory Region of Influence Population, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Bannock County	71,800	76,500	79,800	82,800	86,000	89,300	95,200	101,600
Pocatello	50,300	53,500	55,800	57,900	60,200	62,500	66,600	71,100
Bingham County	41,500	44,200	46,100	47,800	49,700	51,600	55,000	58,700
Blackfoot	10,900	11,600	12,100	12,600	13,100	13,600	14,500	15,400
Bonneville County	80,200	85,500	89,100	92,400	96,000	99,700	106,400	113,400
Idaho Falls	50,600	53,900	56,100	58,200	60,500	62,900	67,000	71,500
Butte County	3,100	3,300	3,400	3,600	3,700	3,800	4,100	4,400
Jefferson County	18,700	19,900	20,700	21,500	22,300	23,200	24,700	26,400
Rigby	3,100	3,300	3,400	3,600	3,700	3,800	4,100	4,400
ROI Total	215,300	229,400	239,100	248,100	257,700	267,600	285,400	304,500

Note: City values are included within county totals.

Source: Census 1993n; Census 1995a; DOC 1994j; DOC 1996a; DOC 1996b.

Table L.1–30. Idaho National Engineering Laboratory Region of Influence Total Number of Owner and Renter Housing Units, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Bannock County	26,800	28,600	29,800	30,900	32,100	33,300	35,600	37,900
Pocatello	19,800	21,100	22,000	22,800	23,700	24,600	26,300	28,000
Bingham County	13,200	14,100	14,700	15,200	15,800	16,400	17,500	18,700
Blackfoot	4,000	4,200	4,400	4,600	4,800	4,900	5,300	5,600
Bonneville County	27,900	29,700	30,900	32,100	33,300	34,600	36,900	39,400
Idaho Falls	19,100	20,300	21,200	22,000	22,800	23,700	25,300	26,900
Butte County	1,100	1,200	1,300	1,300	1,400	1,400	1,500	1,600
Jefferson County	5,600	6,000	6,300	6,500	6,700	7,000	7,500	8,000
Rigby	1,100	1,100	1,200	1,200	1,300	1,300	1,400	1,500
ROI Total	74,600	79,600	83,000	86,000	89,300	92,700	99,000	105,600

Note: City values are included within county totals.
Source: Census 1991n; Table L.1–29.

Table L.1–31. Idaho National Engineering Laboratory Region of Influence Total Student Enrollment, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Bannock County	15,930	16,970	17,690	18,360	19,060	19,800	21,120	22,530
Marrsh Valley	1,740	1,850	1,930	2,010	2,080	2,160	2,310	2,460
Pocatello	14,190	15,120	15,760	16,350	16,980	17,640	18,810	20,070
Bingham County	11,730	12,510	13,040	13,540	14,050	14,590	15,570	16,610
Aberdeen	1,010	1,080	1,120	1,170	1,210	1,260	1,340	1,430
Blackfoot	4,570	4,870	5,080	5,270	5,470	5,680	6,060	6,460
Firth	1,140	1,220	1,270	1,320	1,370	1,420	1,520	1,620
Snake River	2,590	2,760	2,880	2,990	3,100	3,220	3,440	3,670
Shelley	2,420	2,580	2,690	2,790	2,900	3,010	3,210	3,430
Bonneville County	19,300	20,560	21,430	22,230	23,100	23,990	25,580	27,290
Bonneville	7,780	8,290	8,640	8,960	9,310	9,670	10,310	11,000
Idaho Falls	11,420	12,170	12,680	13,160	13,670	14,200	15,140	16,150
Swan Valley	100	100	110	110	120	120	130	140
Butte County	740	790	820	850	890	920	980	1,050
Arco	740	790	820	850	890	920	980	1,050
Jefferson County	5,760	6,130	6,400	6,640	6,890	7,160	7,630	8,150
Jefferson	4,230	4,500	4,690	4,870	5,060	5,250	5,600	5,980
Ririe	760	810	850	880	910	950	1,010	1,080
West Jefferson	770	820	860	890	920	960	1,020	1,090
ROI Total	53,460	56,960	59,380	61,620	63,990	66,460	70,880	75,630

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–29.

Table L.1–32. Idaho National Engineering Laboratory Region of Influence Total Number of Teachers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Bannock County	872	929	968	1,004	1,043	1,084	1,156	1,233
Marsh Valley	105	112	117	121	126	131	140	149
Pocatello	767	817	851	883	917	953	1,016	1,084
Bingham County	629	671	697	724	753	782	834	889
Aberdeen	60	64	66	69	72	74	79	84
Blackfoot	264	282	293	304	316	329	350	374
Firth	61	65	67	70	73	76	81	86
Snake River	135	143	150	155	161	167	179	190
Shelley	109	117	121	126	131	136	145	155
Bonneville County	1,043	1,110	1,159	1,202	1,248	1,297	1,383	1,474
Bonneville	429	457	477	495	514	534	569	607
Idaho Falls	609	648	676	701	728	757	807	860
Swan Valley	5	5	6	6	6	6	7	7
Butte County	46	49	51	52	55	57	60	64
Arco	46	49	51	52	55	57	60	64
Jefferson County	300	320	333	344	359	373	397	424
Jefferson	215	229	238	247	257	267	285	304
Ririe	39	42	44	45	47	49	52	56
West Jefferson	46	49	51	52	55	57	60	64
ROI Total	2,890	3,079	3,208	3,326	3,458	3,593	3,830	4,084

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–29.

Table L.1–33. Idaho National Engineering Laboratory Region of Influence Total Number of Sworn Police Officers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Bannock County	55	58	61	63	65	68	72	77
Pocatello	80	85	89	92	96	99	106	113
Bingham County	39	42	44	45	47	49	52	56
Blackfoot	19	20	21	22	23	24	26	27
Bonneville County	47	50	52	54	56	58	62	66
Idaho Falls	83	88	92	96	99	103	110	117
Butte County	4	4	4	5	5	5	5	6
Jefferson County	11	12	12	13	13	14	15	16
Rigby	6	6	7	7	7	8	8	9
ROI Total	344	365	382	397	411	428	456	487

Source: DOJ 1995a; Table L.1–29.

Table L.1–34. Idaho National Engineering Laboratory Region of Influence Total Number of Firefighters, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Bannock County	50	53	56	58	60	62	66	71
Pocatello	71	76	79	82	85	88	94	100
Bingham County	56	60	62	65	67	70	74	79
Blackfoot	40	43	44	46	48	50	53	57
Bonneville County	35	37	39	40	42	44	46	49
Idaho Falls	88	94	98	101	105	109	117	124
Butte County	23	25	26	26	28	29	30	33
Jefferson County	90	96	100	104	108	112	119	127
Rigby	12	13	13	14	14	15	16	17
ROI Total	465	497	517	536	557	579	615	657

Source: Socio 1996a; Table L.1–29.

Table L.1–35. Idaho National Engineering Laboratory Region of Influence Hospital Occupancy Rates, 1995-2040

County/City	1995 (percent)	2000 (percent)	2005 (percent)	2010 (percent)	2015 (percent)	2020 (percent)	2030 (percent)	2040 (percent)
Bannock County	49	52	54	56	58	60	64	69
Bingham County	62	66	68	71	74	77	82	87
Bonneville County	50	53	55	57	59	62	66	70
Butte County	NA	NA	NA	NA	NA	NA	NA	NA
Jefferson County	NH	NH	NH	NH	NH	NH	NH	NH
ROI Average	51	54	57	59	61	63	68	72

Note: NA=not available. Some hospitals in Butte County unable to provide occupancy data; NH=no hospitals are located in Jefferson County.

Source: AHA 1995a; Table L.1–29.

Table L.1–36. Idaho National Engineering Laboratory Region of Influence Total Number of Doctors, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Bannock County	112	120	125	129	135	140	149	159
Bingham County	21	23	24	24	25	26	28	30
Bonneville County	131	139	145	150	156	162	173	185
Butte County	0	0	0	0	0	0	0	0
Jefferson County	3	3	3	3	4	4	4	4
ROI Total	267	285	297	306	320	332	354	378

Source: AMA 1995a; Table L.1–29.

Table L.1–37. Pantex Plant Regional Economic Area Employment and Economy, 1995-2040

Regional Economic Area	1995	2000	2005	2010	2015	2020	2030	2040
Civilian labor force	229,100	233,000	235,500	239,000	243,000	247,700	257,300	267,300
Total employment	218,100	221,800	224,200	227,500	231,300	235,800	244,900	254,400
Unemployment rate (percent)	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Total personal income (thousands of dollars)	8,942,433	9,251,512	9,450,250	9,732,031	10,059,136	10,450,770	11,276,590	12,167,609
Per capita income (dollars)	19,435	19,768	19,979	20,275	20,613	21,010	21,825	22,671

Source: Census 1993m; Census 1993w; Census 1994o; Census 1995a; DOC 1994j; DOC 1995a; DOC 1996a; DOC 1996b; DOL 1995a.

Table L.1–38. Pantex Plant Region of Influence Population, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Armstrong County	2,100	2,100	2,100	2,200	2,200	2,300	2,300	2,400
Carson County	6,600	6,700	6,800	6,900	7,000	7,100	7,400	7,700
Potter County	103,300	105,000	106,200	107,700	109,700	111,600	116,000	120,500
Amarillo	165,600	168,400	170,200	172,800	175,900	179,000	186,000	193,200
Randall County	94,400	96,000	97,100	98,500	100,300	102,100	106,000	110,200
ROI Total	206,400	209,800	212,200	215,300	219,200	223,100	231,700	240,800

Note: Amarillo is divided across Potter and Randall Counties. The population shown for Amarillo is for the whole city. Potter and Randall County totals represent their share of Amarillo.

Source: Census 1993w; Census 1994o; Census 1995a; DOC 1994j; DOC 1996a; DOC 1996b.

Table L.1–39. Pantex Plant Region of Influence Total Number of Owner and Renter Housing Units, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Armstrong County	800	800	800	900	900	900	900	1,000
Carson County	2,600	2,600	2,700	2,700	2,800	2,800	2,900	3,000
Potter County	43,300	44,000	44,500	45,100	45,900	46,800	48,600	50,500
Amarillo	69,600	70,800	71,600	72,700	74,000	75,300	78,200	81,200
Randall County	38,700	39,300	39,700	40,300	41,100	41,800	43,400	45,100
ROI Total	85,400	86,700	87,700	89,000	90,700	92,300	95,800	99,600

Note: Amarillo is divided across Potter and Randall Counties. The value shown for Amarillo is for the whole city. Potter and Randall County totals each represent their share of Amarillo.

Source: Census 1991m; Table L.1–38.

Table L.1–40. Pantex Plant Region of Influence Total Student Enrollment, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Armstrong County	400	410	410	420	430	440	450	470
Claude	400	410	410	420	430	440	450	470
Carson County	1,430	1,450	1,470	1,490	1,520	1,550	1,610	1,670
Groom	230	230	240	240	240	250	260	270
Panhandle	730	740	750	760	780	790	820	850
White Deer	470	480	480	490	500	510	530	550
Potter County	2,390	2,440	2,460	2,500	2,560	2,590	2,700	2,810
Bushland	380	390	390	400	410	410	430	450
Highland Park	690	700	710	720	740	750	780	810
River Road	1,320	1,350	1,360	1,380	1,410	1,430	1,490	1,550
Amarillo	29,020	29,520	29,840	30,280	30,820	31,380	32,590	33,860
Randall County	6,480	6,590	6,660	6,760	6,880	7,000	7,270	7,550
Canyon	6,480	6,590	6,660	6,760	6,880	7,000	7,270	7,550
ROI Total	39,720	40,410	40,840	41,450	42,210	42,960	44,620	46,360

Note: Amarillo School District values not included within county totals; bolded areas are county totals, and unbolded areas are school districts.

Source: Socio 1996a; Table L.1–38.

Table L.1–41. Pantex Plant Region of Influence Total Number of Teachers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Armstrong County	33	34	34	35	35	36	37	39
Claude	33	34	34	35	35	36	37	39
Carson County	122	124	126	128	130	133	137	142
Groom	20	20	21	21	21	22	23	23
Panhandle	59	60	61	62	63	64	66	69
White Deer	43	44	44	45	46	47	48	50
Potter County	165	169	171	173	176	179	185	194
Bushland	27	28	28	28	29	29	30	32
Highland Park	57	58	59	60	61	62	64	67
River Road	81	83	84	85	86	88	91	95
Amarillo	1,746	1,776	1,795	1,821	1,854	1,887	1,961	2,037
Randall County	372	379	383	388	395	402	418	434
Canyon	372	379	383	388	395	402	418	434
ROI Total	2,438	2,482	2,509	2,545	2,590	2,637	2,738	2,846

Note: Amarillo School District values not included within county totals; bolded areas are county totals, and unbolded areas are school districts.

Source: Socio 1996a; Table L.1–38.

Table L.1–42. Pantex Plant Region of Influence Total Number of Sworn Police Officers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Armstrong County	3	3	3	3	3	3	3	4
Carson County	5	5	5	5	5	5	6	6
Potter County	126	129	130	132	134	137	142	147
Amarillo	254	258	261	265	270	274	285	296
Randall County	76	78	78	80	81	82	86	89
ROI Total	463	473	477	485	493	501	522	542

Note: Amarillo City values not included within county totals. Non-ROI cities included within county numbers.

Source: DOJ 1995a; Table L.1–38.

Table L.1–43. Pantex Plant Region of Influence Total Number of Firefighters, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Armstrong County	39	40	41	41	42	43	44	46
Carson County	90	92	93	94	96	98	101	105
Potter County	0	0	0	0	0	0	0	0
Amarillo	214	217	220	223	227	231	240	249
Randall County	69	70	71	72	74	75	78	81
ROI Total	412	419	425	430	439	447	463	481

Note: Amarillo City values not included within county totals. Non-ROI cities included within county numbers.

Source: Socio 1996a; Table L.1–38.

Table L.1–44. Pantex Plant Region of Influence Hospital Occupancy Rates, 1995-2040

County/City	1995 (percent)	2000 (percent)	2005 (percent)	2010 (percent)	2015 (percent)	2020 (percent)	2030 (percent)	2040 (percent)
Armstrong County	NH	NH	NH	NH	NH	NH	NH	NH
Carson County	NH	NH	NH	NH	NH	NH	NH	NH
Potter County	56	57	58	59	60	61	63	66
Randall County	32	33	33	33	34	35	36	37
ROI Average	56	57	57	58	59	60	62	65

Note: NH=No hospitals located in Armstrong or Carson Counties.
Source: AHA 1995a; Table L.1–38.

Table L.1–45. Pantex Plant Region of Influence Total Number of Doctors, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Armstrong County	0	0	0	0	0	0	0	0
Carson County	0	0	0	0	0	0	0	0
Potter County	396	403	407	413	421	428	445	462
Randall County	12	12	12	13	13	13	14	14
ROI Total	408	415	419	426	434	441	459	476

Source: AMA 1995a; Table L.1–38.

Table L.1–46. Oak Ridge Reservation Regional Economic Area Employment and Economy, 1995-2040

Regional Economic Area	1995	2000	2005	2010	2015	2020	2030	2040
Civilian labor force	482,200	512,900	537,400	562,400	587,400	610,900	653,400	698,900
Total employment	458,800	488,100	511,400	535,200	558,900	681,300	621,800	665,000
Unemployment rate (percent)	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Total personal income (thousands of dollars)	16,482,992	18,654,590	20,477,380	22,427,539	24,466,384	26,460,927	30,273,609	34,635,650
Per capita income (dollars)	18,190	19,351	20,275	21,218	22,162	23,047	24,652	26,368

Source: Census 1993b; Census 1995a; DOC 1994j; DOC 1995a; DOC 1996a; DOC 1996b; DOL 1991a; DOL 1995a; OR LMES 1995e.

Table L.1–47. Oak Ridge Reservation Region of Influence Population, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Anderson County	72,100	76,700	80,400	84,100	87,700	91,400	97,700	104,500
Clinton	10,400	11,000	11,500	12,100	12,600	13,100	14,000	15,000
Oak Ridge	28,600	30,400	31,800	33,300	34,700	36,200	38,700	41,400
Knox County	361,900	385,000	403,400	422,100	440,000	458,500	490,500	524,600
Knoxville	171,400	182,400	191,100	200,000	208,400	217,200	232,300	248,500
Loudon County	35,500	37,800	39,600	41,400	43,200	45,000	48,100	51,500
Lenoir City	8,800	9,300	9,800	10,200	10,700	11,100	11,900	12,700
Roane County	49,100	52,200	54,700	57,300	59,700	62,200	66,600	71,200
Harriman	7,300	7,700	8,100	8,500	8,900	9,200	9,900	10,600
Kingston	5,200	5,500	5,800	6,000	6,300	6,600	7,000	7,500
ROI Total	518,600	551,700	578,100	604,900	630,600	657,100	702,900	751,800

Note: City values are included within county totals.
Source: Census 1993b; Census 1995a; DOC 1994j; DOC 1996a; DOC 1996b.

Table L.1–48. Oak Ridge Reservation Region of Influence Total Number of Owner and Renter Housing Units, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Anderson County	30,000	31,900	33,500	35,000	36,500	38,000	40,700	43,500
Clinton	4,500	4,800	5,000	5,300	5,500	5,700	6,100	6,600
Oak Ridge	12,000	12,700	13,300	13,900	14,500	15,200	16,200	17,300
Knox County	150,600	160,200	167,900	175,700	183,100	190,800	204,100	218,300
Knoxville	76,900	81,800	85,700	89,700	93,500	97,500	104,200	111,500
Loudon County	14,200	15,100	15,900	16,600	17,300	18,000	19,300	20,600
Lenoir City	3,800	4,000	4,200	4,400	4,600	4,800	5,100	5,500
Roane County	19,900	21,200	22,200	23,200	24,200	25,200	27,000	28,800
Harriman	3,100	3,300	3,500	3,700	3,800	4,000	4,300	4,500
Kingston	2,300	2,500	2,600	2,700	2,800	2,900	3,100	3,400
ROI Total	214,700	228,400	239,500	250,500	261,100	272,000	291,100	311,200

Note: City values are included within county totals.
Source: Census 1991c; Table L.1–47.

Table L.1–49. Oak Ridge Reservation Region of Influence Total Student Enrollment, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Anderson County	12,900	13,720	14,380	15,050	15,690	16,340	17,480	18,710
Anderson County	6,890	7,320	7,670	8,030	8,370	8,720	9,330	9,980
Clinton City	1,180	1,260	1,320	1,380	1,440	1,500	1,600	1,720
Oak Ridge	4,830	5,140	5,390	5,640	5,880	6,120	6,550	7,010
Knox County	56,260	59,850	62,700	65,620	68,390	71,280	76,240	81,550
Knox County	56,260	59,850	62,700	65,620	68,390	71,280	76,240	81,550
Loudon County	6,510	6,920	7,260	7,580	7,910	8,250	8,820	9,430
Loudon County	4,590	4,880	5,120	5,350	5,580	5,820	6,220	6,650
Lenoir City	1,920	2,040	2,140	2,230	2,330	2,430	2,600	2,780
Roane County	7,670	8,160	8,550	8,950	9,320	9,710	10,390	11,120
Roane County	5,950	6,330	6,630	6,940	7,230	7,530	8,060	8,620
Harriman	1,720	1,830	1,920	2,010	2,090	2,180	2,330	2,500
ROI Total	83,340	88,650	91,890	97,200	101,310	105,580	112,930	120,810

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–47.

Table L.1–50. Oak Ridge Reservation Region of Influence Total Number of Teachers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Anderson County	912	971	1,017	1,064	1,109	1,156	1,237	1,322
Anderson County	486	517	542	567	591	616	659	704
Clinton City	78	83	87	91	95	99	106	113
Oak Ridge	348	371	388	406	423	441	472	505
Knox County	3,347	3,561	3,731	3,904	4,069	4,241	4,536	4,852
Knox County	3,347	3,561	3,731	3,904	4,069	4,241	4,536	4,852
Loudon County	389	414	434	455	473	494	528	565
Loudon County	278	296	310	325	338	353	377	404
Lenoir City	111	118	124	130	135	141	151	161
Roane County	484	516	540	566	590	615	658	703
Roane County	363	387	405	424	442	461	493	527
Harriman	121	129	135	142	148	154	165	176
ROI Total	5,132	5,462	5,722	5,989	6,241	6,506	6,959	7,442

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–47.

Table L.1–51. Oak Ridge Reservation Region of Influence Total Number of Sworn Police Officers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Anderson County	124	131	138	144	150	157	167	179
Clinton	16	17	18	19	20	21	22	23
Oak Ridge	50	53	55	58	60	63	67	72
Knox County	240	255	267	280	292	304	325	348
Knoxville	341	363	380	398	415	432	462	495
Loudon County	42	44	46	48	50	53	56	60
Lenoir City	14	15	16	17	17	18	19	21
Roane County	49	52	54	57	59	62	66	70
Harriman	13	14	15	15	16	17	18	19
Kingston	8	9	9	9	10	10	11	12
ROI Total	897	953	998	1,045	1,089	1,137	1,213	1,299

Source: DOJ 1995a; Socio 1996a; Table L.1–47.

Table L.1–52. Oak Ridge Reservation Region of Influence Total Number of Firefighters, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Anderson County	183	195	204	213	222	232	248	265
Clinton	16	17	18	19	19	20	22	23
Oak Ridge	46	49	51	54	56	58	62	67
Knox County	200	213	223	233	243	253	271	290
Knoxville	357	380	398	416	434	452	484	518
Loudon County	138	147	154	161	168	175	187	200
Lenoir City	15	16	17	17	18	19	20	22
Roane County	110	117	123	128	134	139	149	159
Harriman	18	19	20	21	22	23	24	26
Kingston	37	39	41	43	45	47	50	54
ROI Total	1,120	1,192	1,249	1,305	1,361	1,418	1,517	1,624

Source: Socio 1996a; Table L.1–47.

Table L.1–53. Oak Ridge Reservation Region of Influence Hospital Occupancy Rates, 1995-2040

County/City	1995 (percent)	2000 (percent)	2005 (percent)	2010 (percent)	2015 (percent)	2020 (percent)	2030 (percent)	2040 (percent)
Anderson County	66	70	74	77	80	84	90	96
Knox County	66	70	73	77	80	83	89	95
Loudon County	32	34	36	38	39	41	44	47
Roane County	52	55	58	61	63	66	71	76
ROI Average	65	69	72	75	78	82	87	93

Source: AHA 1995a; Table L.1–47.

Table L.1–54. Oak Ridge Reservation Region of Influence Total Number of Doctors, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Anderson County	147	156	164	171	178	186	199	213
Knox County	1,123	1,194	1,251	1,310	1,365	1,423	1,522	1,628
Loudon County	24	26	27	28	30	31	33	35
Roane County	28	30	32	33	34	36	38	41
ROI Total	1,322	1,406	1,474	1,542	1,607	1,676	1,792	1,917

Source: AMA 1995a; Table L.1–47.

Table L.1–55. Savannah River Site Regional Economic Area Employment and Economy, 1995-2040

Regional Economic Area	1995	2000	2005	2010	2015	2020	2030	2040
Civilian labor force	260,400	275,600	288,600	302,500	316,300	329,700	354,000	380,000
Total employment	242,900	257,000	269,200	282,100	295,100	307,600	330,200	354,500
Unemployment rate (percent)	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
Total personal income (thousands of dollars)	10,070,574	11,281,795	12,370,855	13,590,502	14,867,480	16,152,064	18,615,578	21,454,828
Per capita income (dollars)	17,332	18,334	19,209	20,134	21,059	21,950	23,564	25,297

Source: Census 1993c; Census 1993e; Census 1995a; DOC 1994j; DOC 1995a; DOC 1996a; DOC 1996b; DOL 1991a; DOL 1995a; SRS 1995a:2.

Table L.1–56. Savannah River Site Region of Influence Population, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Aiken County	133,600	141,400	148,000	155,200	162,000	169,200	181,600	195,000
Aiken	25,200	26,700	27,900	29,300	30,600	31,900	34,300	36,800
North Augusta	17,800	18,900	19,800	20,700	21,600	22,600	24,200	26,000
Allendale County	11,600	11,500	11,700	12,300	12,800	13,400	14,400	15,500
Bamberg County	16,600	16,300	16,700	17,500	18,300	19,200	20,600	22,200
Barnwell County	21,700	22,900	24,000	25,200	26,300	27,400	29,500	31,600
Columbia County	80,800	85,600	89,600	93,900	98,000	102,400	109,900	118,000
Richmond County	193,200	185,200	194,000	203,500	212,900	222,700	239,600	257,900
Augusta	42,900	41,300	43,100	45,300	47,300	49,500	53,300	57,300
ROI Total	457,500	462,900	484,000	507,600	530,300	554,300	595,600	640,200

Note: City values are included within county totals.

Source: Census 1993c; Census 1993e; Census 1995a; DOC 1994j; DOC 1996a; DOC 1996b.

Table L.1–57. Savannah River Site Region of Influence Total Number of Owner and Renter Housing Units, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Aiken County	52,000	55,000	57,600	60,400	63,000	65,800	70,600	75,800
Aiken	10,400	11,000	11,500	12,100	12,600	13,200	14,200	15,200
North Augusta	7,700	8,200	8,600	9,000	9,400	9,800	10,500	11,300
Allendale County	3,900	3,900	3,900	4,100	4,300	4,500	4,800	5,200
Bamberg County	5,700	5,600	5,700	6,000	6,300	6,600	7,100	7,600
Barnwell County	7,900	8,400	8,700	9,200	9,600	10,000	10,700	11,500
Columbia County	27,700	29,400	30,800	32,200	33,700	35,100	37,700	40,500
Richmond County	74,200	71,100	74,500	78,200	81,800	85,500	92,000	99,100
Augusta	19,300	18,600	19,400	20,400	21,300	22,300	24,000	25,800
ROI Total	171,400	173,400	181,200	190,100	198,700	207,500	222,900	239,700

Note: City values are included within county totals.

Source: Census 1991a; Census 1991b; Table L.1–56.

Table L.1–58. Savannah River Site Region of Influence Total Student Enrollment, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Aiken County	25,610	27,110	28,380	29,750	31,060	32,430	34,820	37,380
Aiken County	25,610	27,110	28,380	29,750	31,060	32,430	34,820	37,380
Allendale County	2,340	2,310	2,350	2,460	2,570	2,690	2,900	3,120
Allendale County	2,340	2,310	2,350	2,460	2,570	2,690	2,900	3,120
Bamberg County	3,130	3,080	3,160	3,310	3,460	3,620	3,900	4,190
District #1	1,820	1,790	1,840	1,930	2,010	2,110	2,270	2,440
District #2	1,310	1,290	1,320	1,380	1,450	1,510	1,630	1,750
Barnwell County	4,990	5,290	5,540	5,810	6,060	6,320	6,790	7,280
District #19	1,270	1,350	1,410	1,480	1,540	1,610	1,730	1,850
District #29	1,030	1,090	1,140	1,200	1,250	1,300	1,400	1,500
District #45	2,690	2,850	2,990	3,130	3,270	3,410	3,660	3,930
Columbia County	16,260	17,210	18,020	18,890	19,720	20,590	22,110	23,730
Columbia County	16,260	17,210	18,020	18,890	19,720	20,590	22,110	23,730
Richmond County	34,400	32,990	34,550	36,240	37,910	39,660	42,670	45,920
Richmond County	34,400	32,990	34,550	36,240	37,910	39,660	42,670	45,920
ROI Total	86,730	87,990	92,000	96,460	100,780	105,310	113,190	121,620

Note: Bolded areas are county totals and unbolded areas are school districts.

Source: Socio 1996a; Table L.1–56.

Table L.1–59. Savannah River Site Region of Influence Total Number of Teachers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Aiken County	1,345	1,424	1,491	1,563	1,632	1,704	1,829	1,963
Aiken County	1,345	1,424	1,491	1,563	1,632	1,704	1,829	1,963
Allendale County	159	158	160	168	176	184	198	213
Allendale County	159	158	160	168	176	184	198	213
Bamberg County	224	221	226	237	248	259	279	300
District #1	124	122	125	131	137	143	154	166
District #2	100	99	101	106	111	116	125	134
Barnwell County	299	316	331	347	362	378	405	436
District #19	76	80	84	88	92	96	103	111
District #29	68	72	75	79	82	86	92	99
District #45	155	164	172	180	188	196	210	226
Columbia County	905	958	1,003	1,052	1,098	1,146	1,231	1,321
Columbia County	905	958	1,003	1,052	1,098	1,146	1,231	1,321
Richmond County	2,034	1,950	2,043	2,143	2,242	2,345	2,523	2,715
Richmond County	2,034	1,950	2,043	2,143	2,242	2,345	2,523	2,715
ROI Total	4,966	5,027	5,254	5,510	5,758	6,016	6,465	6,948

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–56.

Table L.1–60. Savannah River Site Region of Influence Total Number of Sworn Police Officers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Aiken County	100	106	111	116	121	127	136	146
Aiken	83	88	92	96	101	105	113	121
North Augusta	49	51	54	56	59	61	66	71
Allendale County	19	19	19	20	21	22	23	25
Bamberg County	24	23	24	25	26	28	30	32
Barnwell County	36	39	40	42	44	46	50	53
Columbia County	154	163	170	179	186	195	209	224
Richmond County	320	307	321	337	353	369	397	427
Augusta	167	161	168	176	184	193	207	223
ROI Total	952	957	999	1,047	1,095	1,146	1,231	1,322

Source: DOJ 1995a; Table L.1–56.

Table L.1–61. Savannah River Site Region of Influence Total Number of Firefighters, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Aiken County	375	397	416	436	455	475	510	547
Aiken	100	106	111	116	121	127	136	146
North Augusta	45	48	50	52	55	57	61	66
Allendale County	82	81	82	86	90	94	102	109
Bamberg County	155	152	156	164	171	179	193	207
Barnwell County	90	95	100	105	109	114	122	131
Columbia County	196	207	217	228	238	248	266	286
Richmond County	182	174	183	192	201	210	226	243
Augusta	138	133	139	146	152	159	171	184
ROI Total	1,363	1,393	1,454	1,525	1,592	1,663	1,787	1,919

Source: Socio 1996a; Table L.1–56.

Table L.1–62. Savannah River Site Region of Influence Hospital Occupancy Rates, 1995-2040

County/City	1995 (percent)	2000 (percent)	2005 (percent)	2010 (percent)	2015 (percent)	2020 (percent)	2030 (percent)	2040 (percent)
Aiken County	NA	NA	NA	NA	NA	NA	NA	NA
Allendale County	67	66	67	71	74	77	83	90
Bamberg County	72	71	73	76	80	84	90	97
Barnwell County	47	50	52	55	57	60	64	69
Columbia County	NH	NH	NH	NH	NH	NH	NH	NH
Richmond County	61	58	61	64	67	70	75	81
ROI Average	65	65	68	72	75	78	84	90

Note: NA=not available. Some hospitals in Aiken County are unable to provide occupancy data. NH=No hospitals are located in Columbia County.

Source: AHA 1995a; Table L.1–56.

Table L.1–63. Savannah River Site Region of Influence Total Number of Doctors, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Aiken County	145	153	160	168	175	183	197	211
Allendale County	6	6	6	6	7	7	7	8
Bamberg County	8	8	8	8	9	9	10	11
Barnwell County	8	9	9	9	10	10	11	12
Columbia County	212	225	235	247	258	269	289	310
Richmond County	971	931	975	1,023	1,070	1,119	1,204	1,296
ROI Total	1,350	1,332	1,393	1,461	1,529	1,597	1,458	1,848

Source: AMA 1995a; Table L.1–56.

Table L.1–64. Rocky Flats Environmental Technology Site Regional Economic Area Employment and Economy, 1995-2040

Regional Economic Area	1995	2000	2005	2010	2015	2020	2030	2040
Civilian labor force	1,900,800	2,070,300	2,219,300	2,362,800	2,502,300	2,629,900	2,854,200	3,097,500
Total employment	1,822,900	1,985,400	2,128,300	2,265,900	2,399,700	2,522,100	2,737,200	2,970,500
Unemployment rate (percent)	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Total personal income (thousands of dollars)	77,373,382	91,785,863	105,476,299	119,552,501	134,090,993	148,119,250	174,451,599	205,465,262
Per capita income (dollars)	22,721	24,747	26,528	28,243	29,911	31,437	34,117	37,025

Source: Census 1993t; Census 1993u; Census 1993v; Census 1995a; CO DIS 1994a; DOC 1994j; DOC 1995a; DOC 1996a; DOC 1996b; DOL 1991a; DOL 1995a; RFETS 1995a:1.

Table L.1–65. Rocky Flats Environmental Technology Site Region of Influence Population, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Adams County	300,200	333,600	363,700	392,300	418,000	445,400	489,200	537,300
Westminster	88,800	98,800	107,600	116,100	123,700	131,800	144,800	159,000
Thornton	64,400	71,600	78,000	84,200	89,700	95,500	104,900	115,300
Arapahoe County	452,500	503,000	548,200	591,400	630,200	671,400	737,500	810,000
Boulder County	254,800	283,200	308,700	333,000	354,800	378,100	415,300	456,100
Broomfield	28,000	31,100	33,900	36,600	39,000	41,500	45,600	50,100
Longmont	57,400	63,800	69,600	75,100	80,000	85,200	93,600	102,800
Denver County	497,100	507,900	514,600	522,200	529,900	537,800	553,700	570,000
Jefferson County	487,100	541,400	590,100	636,600	678,300	722,800	793,800	871,900
Arvada	97,400	108,300	118,000	127,300	135,700	144,600	158,800	174,400
ROI Total	1,991,700	2,169,100	2,325,300	2,475,500	2,611,200	2,755,500	2,989,500	3,245,300

Note: Cities split across county lines were analyzed in the county where a majority of the population resides. All city values are included within county totals.
Source: Census 1993v; Census 1995a; CO DIS 1994a; DOC 1994j; DOC 1996a; DOC 1996b.

Table L.1–66. Rocky Flats Environmental Technology Site Region of Influence Total Number of Owner and Renter Housing Units, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Adams County	118,100	131,300	143,100	154,400	164,500	155,900	192,600	211,500
Westminster	35,100	39,000	42,500	45,800	48,900	44,800	57,200	62,800
Thornton	23,800	26,400	28,800	31,100	33,100	30,600	38,700	42,600
Arapahoe County	192,400	213,900	233,100	251,500	268,000	251,700	313,600	344,400
Boulder County	103,300	114,800	125,200	135,000	143,900	135,800	168,400	184,900
Broomfield	10,300	11,400	12,500	13,500	14,300	9,000	16,800	18,400
Longmont	22,600	25,100	27,400	29,500	31,500	30,200	36,800	40,500
Denver County	247,600	253,000	256,300	260,100	264,000	339,000	275,800	283,900
Jefferson County	193,800	215,400	234,800	253,300	269,900	255,000	315,900	346,900
Arvada	36,300	40,300	43,900	47,400	50,500	47,600	59,100	64,900
ROI Total	855,200	928,400	992,500	1,054,300	1,110,300	1,137,400	1,266,300	1,371,600

Note: City values are included within county totals.
Source: Census 1991k; Table L.1–65.

Table L.1–67. Rocky Flats Environmental Technology Site Region of Influence Total Student Enrollment, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Adams County	58,990	65,590	71,460	77,100	82,170	87,540	96,160	105,610
Adams County	6,540	7,270	7,920	8,550	9,110	9,710	10,660	11,710
Bennet	1,050	1,170	1,270	1,370	1,460	1,560	1,710	1,880
Brighton	4,410	4,900	5,340	5,760	6,140	6,540	7,190	7,890
Mappleton	4,990	5,550	6,040	6,520	6,950	7,400	8,130	8,930
Northglenn-Thornton	27,020	30,040	32,740	35,320	37,640	40,100	44,050	48,380
Strasburg	220	250	270	290	310	330	360	400
Westminster City	14,760	16,410	17,880	19,290	20,560	21,900	24,060	26,420
Arapahoe County	87,180	96,920	105,640	113,950	121,430	129,370	142,100	156,070
Adams-Arapahoe/Aurora	27,990	31,110	33,910	36,580	38,980	41,530	45,620	50,100
Byers	380	420	460	490	530	560	610	670
Cherry Creek	36,210	40,250	43,870	47,330	50,430	53,730	59,010	64,820
Englewood	4,370	4,860	5,290	5,710	6,080	6,480	7,120	7,820
Littleton	16,020	17,810	19,420	20,940	22,320	23,780	26,120	28,690
Sheridan	2,020	2,250	2,450	2,650	2,820	3,000	3,300	3,620
Deer Trail	190	220	240	250	270	290	320	350
Boulder County	41,570	46,210	50,360	54,330	57,890	61,680	67,750	74,410
Boulder Valley	25,170	27,980	30,490	32,900	35,050	37,350	41,020	45,050
St. Vrain	16,400	18,230	19,870	21,430	22,840	24,330	26,730	29,360
Denver County	63,220	64,590	65,440	66,410	67,400	68,400	70,420	72,490
Denver County	63,220	64,590	65,440	66,410	67,400	68,400	70,420	72,490
Jefferson County	85,880	95,470	104,050	112,250	119,610	127,440	139,980	153,740
Jefferson County	85,880	95,470	104,050	112,250	119,610	127,440	139,980	153,740
ROI Total	336,840	368,780	396,950	424,040	448,500	474,430	516,410	562,320

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–65.

Table L.1–68. Rocky Flats Environmental Technology Site Region of Influence Total Number of Teachers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Adams County	3,034	3,374	3,678	3,967	4,226	4,504	4,946	5,433
Adams County	318	354	386	416	443	473	519	570
Bennet	68	76	83	89	95	101	111	122
Brighton	248	276	300	324	345	368	404	444
Mapleton	334	371	404	436	465	495	544	597
Northglenn-Thornton	1,404	1,561	1,702	1,836	1,956	2,084	2,289	2,514
Strasburg	17	19	21	23	24	26	28	31
Westminster City	645	717	782	843	898	957	1,051	1,155
Arapahoe County	5,202	5,783	6,303	6,800	7,246	7,721	8,478	9,313
Adams-Arapahoe/Aurora	1,523	1,693	1,845	1,990	2,121	2,260	2,482	2,726
Byers	30	33	36	39	41	44	48	53
Cherry Creek	2,245	2,496	2,721	2,935	3,127	3,332	3,660	4,020
Englewood	278	309	336	363	387	412	452	497
Littleton	995	1,106	1,206	1,301	1,386	1,477	1,622	1,781
Sheridan	108	120	131	141	151	161	176	194
Deer Trail	23	26	28	31	33	35	38	42
Boulder County	2,220	2,468	2,689	2,901	3,091	3,295	3,618	3,974
Boulder Valley	1,403	1,560	1,700	1,834	1,954	2,083	2,287	2,512
St. Vrain	817	908	989	1,067	1,137	1,212	1,331	1,462
Denver County	3,671	3,751	3,800	3,856	3,914	3,972	4,089	4,209
Denver County	3,671	3,751	3,800	3,856	3,914	3,972	4,089	4,209
Jefferson County	3,624	4,029	4,391	4,737	5,048	5,378	5,907	6,488
Jefferson County	3,624	4,029	4,391	4,737	5,048	5,378	5,907	6,488
ROI Total	17,751	19,405	20,861	22,261	23,525	24,870	27,038	29,417

Note: Bolded areas are county totals and unbolded areas are school districts.

Source: Socio 1996a; Table L.1–65.

Table L.1–69. Rocky Flats Environmental Technology Site Region of Influence Total Number of Sworn Police Officers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Adams County	142	158	172	185	198	211	231	254
Westminster	122	136	148	160	171	182	200	219
Thornton	90	100	109	117	125	133	146	161
Arapahoe County	1,001	1,113	1,213	1,309	1,394	1,486	1,632	1,792
Boulder County	181	201	219	236	252	268	294	323
Broomfield	46	51	56	60	64	68	75	82
Longmont	84	93	101	109	117	124	136	150
Denver County	1,388	1,418	1,437	1,458	1,480	1,502	1,546	1,591
Jefferson County	698	776	846	912	972	1,036	1,138	1,250
Arvada	119	133	145	156	166	177	195	214
ROI Total	3,871	4,179	4,446	4,702	4,939	5,187	5,593	6,036

Source: DOJ 1995a; Socio 1996a; Table L.1–65.

Table L.1–70. Rocky Flats Environmental Technology Site Region of Influence Total Number of Firefighters, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Adams County	1,396	1,552	1,691	1,825	1,944	2,072	2,275	2,499
Westminster	123	137	149	161	171	183	200	220
Thornton	89	99	108	116	124	132	145	159
Arapahoe County	953	1,059	1,155	1,246	1,327	1,414	1,553	1,706
Boulder County	787	875	954	1,029	1,096	1,168	1,283	1,409
Broomfield	39	43	47	51	54	58	64	70
Longmont	68	76	82	89	95	101	111	122
Denver County	875	894	906	919	933	947	975	1,003
Jefferson County	878	976	1,064	1,148	1,223	1,303	1,431	1,572
Arvada	200	222	242	261	279	297	326	358
ROI Total	5,408	5,933	6,398	6,845	7,246	7,675	8,363	9,118

Source: Socio 1996a; Table L.1–65.

Table L.1–71. Rocky Flats Environmental Technology Site Region of Influence Hospital Occupancy Rates, 1995-2040

County/City	1995 (percent)	2000 (percent)	2005 (percent)	2010 (percent)	2015 (percent)	2020 (percent)	2030 (percent)	2040 (percent)
Adams County	23	25	28	30	32	34	37	41
Arapahoe County	50	55	60	65	69	74	81	89
Boulder County	51	57	62	67	71	76	83	92
Denver County	49	60	61	62	63	64	66	68
Jefferson County	45	50	54	59	63	67	73	80
ROI Average	56	61	65	70	73	78	84	91

Source: AHA 1995a; Table L.1–65.

Table L.1–72. Rocky Flats Environmental Technology Site Region of Influence Total Number of Doctors, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Adams County	474	526	574	619	660	703	772	848
Arapahoe County	787	875	953	1,029	1,096	1,168	1,283	1,409
Boulder County	557	619	675	728	776	827	908	998
Denver County	2,668	2,726	2,762	2,803	2,844	2,886	2,972	3,059
Jefferson County	599	666	726	783	834	889	976	1,073
ROI Total	5,085	5,412	5,690	5,962	6,210	6,473	6,911	7,387

Source: AMA 1995a; L.1–65.

Table L.1–73. Los Alamos National Laboratory Regional Economic Area Employment and Economy, 1995-2040

Regional Economic Area	1995	2000	2005	2010	2015	2020	2030	2040
Civilian labor force	119,400	130,000	138,900	147,200	156,000	163,600	176,900	191,100
Total employment	112,100	122,000	130,300	138,100	146,400	153,500	165,900	179,300
Unemployment rate (percent)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Total personal income (thousands of dollars)	4,193,315	4,968,820	5,667,556	6,367,165	7,155,101	7,870,611	9,194,182	10,740,332
Per capita income (dollars)	18,259	19,875	21,227	22,499	23,850	25,014	27,036	29,221

Source: Census 1993m; Census 1995a; DOC 1994j; DOC 1995a; DOC 1996a; DOC 1996b; DOL 1991a; DOL 1995a.

Table L.1–74. Los Alamos National Laboratory Region of Influence Population, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Los Alamos County	18,800	20,500	21,900	23,200	24,500	25,800	27,900	30,200
Rio Arriba County	36,900	40,200	42,900	45,500	48,000	50,600	54,700	59,100
Espanola	10,000	10,800	11,600	12,300	12,900	13,700	14,800	15,900
Santa Fe County	114,200	124,300	132,700	140,700	148,300	156,400	169,000	182,700
Santa Fe	63,600	69,200	73,900	78,400	82,600	87,100	94,200	101,800
ROI Total	169,900	185,000	197,500	209,400	220,800	232,800	251,600	272,000

Note: City values are included within county totals.

Source: Census 1993m; Census 1995a; DOC 1994j; DOC 1996a; DOC 1996b.

Table L.1–75. Los Alamos National Laboratory Region of Influence Total Number of Owner and Renter Housing Units, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Los Alamos County	7,900	8,600	9,100	9,700	10,200	10,800	11,600	12,600
Rio Arriba County	15,400	16,800	17,900	19,000	20,000	21,100	22,800	24,700
Espanola	4,000	4,400	4,700	5,000	5,200	5,500	6,000	6,400
Santa Fe County	47,800	52,100	55,600	59,000	62,200	65,600	70,900	76,600
Santa Fe	28,100	30,600	32,700	34,600	36,500	38,500	41,600	45,000
ROI Total	71,100	77,500	82,600	87,700	92,400	97,500	105,300	113,900

Note: City values are included within county totals.
Source: Census 1991h; Table L.1–74.

Table L.1–76. Los Alamos National Laboratory Region of Influence Total Student Enrollment, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Los Alamos County	3,750	4,090	4,360	4,630	4,880	5,140	5,560	6,010
Los Alamos Public Schools	3,750	4,090	4,360	4,630	4,880	5,140	5,560	6,010
Rio Arriba County	7,280	7,920	8,470	8,980	9,460	9,970	10,790	11,660
Chama Valley Ind. School District #1	600	650	700	740	780	820	890	960
Dulce Ind. School District #21	730	790	850	900	950	1,000	1,080	1,170
Espanola Public School District	5,470	5,950	6,360	6,740	7,100	7,490	8,100	8,750
Jemez Mt. School District #53	480	530	560	600	630	660	720	780
Santa Fe County	15,280	16,640	17,770	18,830	19,860	20,940	22,630	24,460
Pojoaque Valley School District #1	1,890	2,060	2,200	2,330	2,460	2,590	2,800	3,030
Santa Fe Public School District	13,390	14,580	15,570	16,500	17,400	18,350	19,830	21,430
ROI Total	26,310	28,650	30,600	32,440	34,200	36,050	38,980	42,130

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–74.

Table L.1–77. Los Alamos National Laboratory Region of Influence Total Number of Teachers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Los Alamos County	255	278	297	315	332	350	378	409
Los Alamos Public Schools	255	278	297	315	332	350	378	409
Rio Arriba County	402	436	466	494	521	550	596	643
Chama Valley Ind. School District #1	42	45	48	51	54	57	62	67
Dulce Ind. School District #21	42	45	48	51	54	57	62	67
Espanola Public School District	289	314	336	356	375	396	428	462
Jemez Mt. School District #53	29	32	34	36	38	40	44	47
Santa Fe County	861	937	1,002	1,061	1,119	1,180	1,275	1,379
Pojoaque Valley School District #1	109	118	127	134	141	149	161	174
Santa Fe Public School District	753	819	875	927	978	1,031	1,114	1,205
ROI Total	1,518	1,651	1,765	1,870	1,972	2,080	2,249	2,431

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–74.

Table L.1–78. Los Alamos National Laboratory Region of Influence Total Number of Sworn Police Officers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Los Alamos County	42	45	48	51	54	57	62	67
Rio Arriba County	27	30	32	34	36	38	41	44
Espanola	24	27	28	30	32	33	36	39
Santa Fe County	68	74	79	84	89	93	101	109
Santa Fe	106	115	123	130	137	145	157	169
ROI Total	267	291	310	329	348	366	397	428

Source: Socio 1996a; Table L.1–74.

Table L.1–79. Los Alamos National Laboratory Region of Influence Total Number of Firefighters, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Los Alamos County	136	148	158	168	177	186	201	218
Rio Arriba County	276	300	321	340	359	378	409	442
Espanola	24	26	28	30	31	33	36	38
Santa Fe County	257	280	299	317	334	352	381	411
Santa Fe	107	116	124	132	139	147	158	171
ROI Total	800	870	930	987	1,040	1,096	1,185	1,280

Source: Socio 1996a; Table L.1–74.

Table L.1–80. Los Alamos National Laboratory Region of Influence Hospital Occupancy Rates, 1995-2040

County/City	1995 (percent)	2000 (percent)	2005 (percent)	2010 (percent)	2015 (percent)	2020 (percent)	2030 (percent)	2040 (percent)
Los Alamos County	29	32	34	36	38	40	44	47
Rio Arriba County	33	36	38	41	43	45	49	53
Santa Fe County	NA	NA	NA	NA	NA	NA	NA	NA
ROI Total	32	35	37	40	42	44	47	51

Note: NA=not available. Some hospitals in Santa Fe County are unable to provide occupancy data.
Source: AHA 1995a; Table L.1–74.

Table L.1–81. Los Alamos National Laboratory Region of Influence Total Number of Doctors, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
Los Alamos County	46	50	53	56	59	63	68	73
Rio Arriba County	22	24	26	28	29	31	33	36
Santa Fe County	248	270	289	306	322	340	367	397
ROI Total	316	344	368	390	410	434	468	506

Source: AMA 1995a; Table L.1–74.

Table L.1–82. *Representative Site for the Partially Completed Reactor Facility Regional Economic Area Employment and Economy, 1995-2040*

Regional Economic Area	1995	2000	2005	2010	2015	2020	2030	2040
Civilian labor force	471,400	490,900	508,000	526,500	547,100	568,500	607,700	649,600
Total employment	442,500	460,800	476,800	494,200	513,500	533,600	570,400	609,700
Unemployment rate (percent)	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
Total personal income (thousands of dollars)	17,003,392	18,438,982	19,741,968	21,210,463	22,899,239	24,725,301	28,251,496	32,280,578
Per capita income (dollars)	18,086	18,835	19,489	20,200	20,989	21,810	23,313	24,920

Source: BW 1995b:1; Census 1993b; Census 1993p; Census 1995a; DOC 1994j; DOC 1995a; DOC 1996a; DOC 1996b; DOL 1991a; DOL 1995a; NFS 1995b:2; OR LMES 1995e.

Table L.1–83. *Representative Site for the Partially Completed Reactor Facility Region of Influence Population, 1995-2040*

County/City	1995	2000	2005	2010	2015	2020	2030	2040
County A	58,000	60,400	62,400	64,700	67,300	69,900	74,700	79,900
County B	50,000	52,000	53,800	55,800	58,000	60,200	64,400	68,800
County C	260,100	270,900	280,300	290,500	301,900	313,7000	335,300	358,400
City #1	159,200	155,900	159,100	165,000	171,700	178,700	191,400	204,900
City #2	20,400	21,300	22,000	22,800	23,700	24,600	26,300	28,100
ROI Total	368,100	383,300	396,500	411,000	427,200	443,800	474,400	507,100

Note: City values are included within county totals.

Source: Census 1993p; Census 1995a; DOC 1994j; DOC 1996a; DOC 1996b.

Table L.1–84. Representative Site for the Partially Completed Reactor Region of Influence Total Number of Owner and Renter Housing Units, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
County A	23,000	23,900	24,700	25,600	26,700	27,700	29,600	31,600
County B	19,400	20,300	21,000	21,700	22,600	23,500	25,100	26,800
County C	104,400	108,700	112,500	116,600	121,200	125,900	134,600	143,900
City #1	66,500	65,200	66,500	69,000	71,800	74,700	80,000	85,700
City #2	8,800	9,200	9,500	9,900	10,300	10,700	11,400	12,200
ROI Total	146,800	152,900	158,200	163,900	170,500	177,100	189,300	202,300

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Census 1991p; Table L.1–83.

Table L.1–85. Representative Site for the Partially Completed Reactor Region of Influence Total Student Enrollment, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
County A	9,890	10,300	10,660	11,050	11,480	11,930	12,760	13,630
School district #1	7,250	7,550	7,810	8,100	8,410	8,740	9,350	9,990
School district #2	2,640	2,750	2,850	2,950	3,070	3,190	3,410	3,640
County B	9,280	9,660	10,000	10,370	10,770	11,190	11,960	12,790
School district #1	6,430	6,690	6,930	7,180	7,460	7,750	8,280	8,860
School district #2	2,850	2,970	3,070	3,190	3,310	3,440	3,680	3,930
County C	41,920	43,660	45,170	46,830	48,650	50,550	54,040	57,760
School district #1	17,330	18,050	18,670	19,360	20,110	20,900	22,340	23,880
School district #2	24,590	25,610	26,500	27,470	28,540	29,650	31,700	33,880
ROI Total	61,090	63,620	65,830	68,250	70,900	73,670	78,760	84,180

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–83.

Table L.1–86. Representative Site for the Partially Completed Reactor Region of Influence Total Number of Teachers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
County A	640	667	690	715	743	772	825	882
School district #1	479	499	516	535	556	577	617	660
School district #2	161	168	174	180	187	195	208	222
County B	609	634	656	680	706	734	785	839
School district #1	399	416	430	446	463	481	515	550
School district #2	210	218	226	234	243	253	270	289
County C	2,693	2,805	2,902	3,008	3,125	3,247	3,471	3,710
School district #1	1,063	1,107	1,145	1,187	1,233	1,281	1,370	1,464
School district #2	1,630	1,698	1,757	1,821	1,892	1,966	2,101	2,246
ROI Total	3,942	4,106	4,248	4,403	4,574	4,753	5,081	5,431

Note: Bolded areas are county totals and unbolded areas are school districts.
Source: Socio 1996a; Table L.1–83.

Table L.1–87. Representative Site for the Partially Completed Reactor Region of Influence Total Number of Sworn Police Officers, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
County A	51	54	55	57	60	62	66	71
County B	33	35	36	37	39	40	43	46
County C	102	119	126	130	135	140	149	159
City #1	328	321	327	340	353	368	394	422
City #2	34	36	37	38	40	41	44	47
ROI Total	548	565	581	602	627	651	696	745

Source: DOJ 1995a; Table L.1–83.

Table L.1–88. Representative Site for the Partially Completed Reactor Region of Influence Total Number of Firefighters, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
County A	395	411	426	441	458	476	509	544
County B	465	484	501	519	540	561	599	641
County C	425	494	524	542	562	583	621	661
City #1	175	171	175	181	189	196	210	225
City #2	30	31	32	34	35	36	39	41
ROI Total	1,490	1,591	1,658	1,717	1,784	1,852	1,978	2,112

Source: Socio 1996a; Table L.1–83.

Table L.1–89. Representative Site for the Partially Completed Reactor Region of Influence Hospital Occupancy Rates, 1995-2040

County/City	1995 (percent)	2000 (percent)	2005 (percent)	2010 (percent)	2015 (percent)	2020 (percent)	2030 (percent)	2040 (percent)
County A	47	49	51	52	55	57	61	65
County B	71	73	76	79	82	85	91	97
County C	59	61	64	66	68	71	76	81
ROI Average	59	62	64	66	69	72	77	82

Source: AHA 1995a; Table L.1–83.

Table L.1–90. Representative Site for the Partially Completed Reactor Region of Influence Total Number of Doctors, 1995-2040

County/City	1995	2000	2005	2010	2015	2020	2030	2040
County A	30	31	33	34	35	36	39	42
County B	33	35	36	37	39	40	43	46
County C	466	485	502	520	541	562	600	642
ROI Total	529	551	571	591	615	638	682	730

Source: AMA 1995a; Table L.1–83.

Appendix M
Health and Safety

M.1 INTRODUCTION

This appendix presents detailed information on the potential impacts and risks to humans associated with releases of radioactivity and hazardous chemicals from the proposed storage and disposition technologies during normal operations and from postulated accidents. This information is intended to support the public and occupational health and safety assessments described in Sections 4.2 and 4.3 of this programmatic environmental impact statement (PEIS). Section M.2 provides information on normal radiological impacts, Section M.3 provides information on normal hazardous chemical impacts, Section M.4 provides information on human health and epidemiologic studies, and Section M.5 provides information on postulated facility accidents.

M.2 RADIOLOGICAL IMPACTS TO HUMAN HEALTH DURING NORMAL OPERATIONS

This section presents supporting information on the potential radiological impacts of normal operation to humans. This section provides the reader with background information on the nature of radiation (Section M.2.1), the methodology used to calculate radiological impacts (Section M.2.2), radiological releases from fissile material storage and disposition facilities (Section M.2.3), and radiological impacts from various fissile material storage and disposition facilities at each site (Sections M.2.4 through M.2.15).

A further description of the methodology used to assess the normal radiological impacts presented in this appendix and a detailed listing of the data used in the assessments are given in *Health Risk Data for Storage and Disposition of Weapons-Usable Fissile Materials* (Health Risk Data, October 1996).

M.2.1 BACKGROUND

M.2.1.1 Nature of Radiation and Its Effects on Humans

What is Radiation? Humans are constantly exposed to radiation from the solar system and from the earth's rocks and soil. This radiation contributes to the natural background radiation x ray that has always been around us. But there are also manmade sources of radiation, such as medical and dental x rays, household smoke detectors, and materials released from nuclear and coal-fired powerplants.

All matter in the universe is composed of atoms, and radiation comes from the activity of these tiny particles. Atoms are made up of even smaller particles (protons, neutrons, electrons). The number and arrangement of these particles distinguishes one atom from another.

Atoms of different types are known as elements. There are over 100 natural and manmade elements. Some of these elements, such as uranium (U), radium, plutonium (Pu), and thorium, share a very important quality: they are unstable. As they change into more stable forms, invisible waves of energy or particles, known as ionizing radiation, are released. Radioactivity is the emitting of this radiation.

Ionizing radiation refers to the fact that this energy force can ionize, or electrically charge atoms by stripping off electrons. Ionizing radiation can cause a change in the chemical composition of many things, including living tissue (organs), which can affect the way they function.

The effects on people of radiation that is emitted during disintegration (decay) of a radioactive substance depends on the kind of radiation (alpha and beta particles, and gamma and x rays) and the total amount of

radiation energy absorbed by the body. The total energy absorbed per unit quantity of tissue is referred to as absorbed dose. The absorbed dose, when multiplied by certain quality factors and factors that take into account different sensitivities of various tissues, is referred to as effective dose equivalent, or where the context is clear, simply dose. The common unit of effective dose equivalent is the roentgen equivalent man (rem) (1 rem equals 1,000 millirem [mrem]).

Alpha particles are the heaviest of these direct types of ionizing radiation, and despite a speed of about 16,000 kilometers (km)/second (s) (9,940 miles [mi]/s), they can travel only several centimeters in air. Alpha particles lose their energy almost as soon as they collide with anything. They can easily be stopped by a sheet of paper or the skin's surface.

Beta particles are much lighter than alpha particles. They can travel as much as 160,000 km/s (99,400 mi/s) and can travel in the air for a distance of about 3 meters (m) (9.8 feet [ft]). Beta particles can pass through a sheet of paper, but may be stopped by a thin sheet of aluminum foil or glass.

Gamma and x rays, unlike alpha or beta particles, are waves of pure energy. Gamma rays travel at the speed of light (300,000 km/s [186,000 mi/s]). Gamma radiation is very penetrating and requires a thick wall of concrete, lead, or steel to stop it.

The neutron is another particle which contributes to radiation exposure, both directly and indirectly. The latter is associated with the gamma rays and alpha particles which are emitted following neutron capture in matter. A neutron has about one quarter the weight of an alpha particle and can travel at speeds of up to 39,000 km/s (24,200 mi/s). Neutrons are more penetrating than beta particles, but less than gamma rays.

The radioactivity of a material decreases with time. The time it takes a material to lose half of its original radioactivity is its half-life. For example, a quantity of iodine-131, a material that has a half-life of 8 days, will lose one-half of its radioactivity in that amount of time. In 8 more days, one-half of the remaining radioactivity will be lost, and so on. Eventually, the radioactivity will essentially disappear. Each radioactive element has a characteristic half-life. The half-lives of various radioactive elements may vary from millionths of a second to millions of years.

As a radioactive element gives up its radioactivity, it often changes to an entirely different element, one that may or may not be radioactive. Eventually, a stable element is formed. This transformation may take place in several steps and is known as a decay chain. Radium, for example, is a naturally occurring radioactive element with a half-life of 1,622 years. It emits an alpha particle and becomes radon, a radioactive gas with a half-life of only 3.8 days. Radon decays to polonium and through a series of steps to bismuth and ultimately to lead.

Units of Radiation Measure. Scientists and engineers use a variety of units to measure radiation. These different units can be used to determine the amount, type and intensity of radiation. Just as heat can be measured in terms of its intensity or its effects using units of calories or degrees, amount of radiation can be measured in curies (Ci), radiation absorbed doses (rads), or rems.

The curie, named after the French scientists Marie and Pierre Curie, describes the "intensity" of a sample of radioactive material. The rate of decay of 1 gram of radium is the basis of this unit of measure. It is equal to 3.7×10^{10} disintegrations (decays)/s.

The total energy absorbed per unit quantity of tissue is referred to as absorbed dose. The rad is the unit of measurement for the physical absorption of radiation. Much like sunlight heats the pavement by giving up an amount of energy to it, radiation gives up rads of energy to objects in its path. One rad is equal to the amount of radiation that leads to the deposition of 0.01 joule of energy per kilogram of absorbing material.

A rem is a measurement of the dose from radiation based on its biological effects. The rem is used to measure the effects of radiation on the body, much like degrees Centigrade can be used to measure the effects of sunlight heating pavement. Thus, 1 rem of one type of radiation is presumed to have the same biological effects as 1 rem of any other kind of radiation. This standard allows comparison of the biological effects of radionuclides that emit different types of radiation.

An individual may be exposed to ionizing radiation externally from a radioactive source outside the body, and/or internally from ingesting radioactive material. The external dose is different from the internal dose. An external dose is delivered only during the actual time of exposure to the external radiation source. An internal dose, however, continues to be delivered as long as the radioactive source is in the body, although both radioactive decay and elimination of the radionuclide by ordinary metabolic processes decrease the dose rate with the passage of time. The dose from internal exposure is calculated over 50 years following the initial exposure.

The three types of doses calculated in this include an external dose, an internal dose, and a combined external and internal dose. Each type of dose is discussed separately below.

External Dose. The external dose can arise from several different pathways. All these pathways have in common the fact that the radiation causing the exposure is external to the body. In this PEIS, these pathways include exposure to a cloud of radiation passing overhead of the receptor, standing on ground which is contaminated with radioactivity, swimming in contaminated water, and boating in contaminated water. The appropriate measure of dose is called the effective dose equivalent. It should be noted that if the receptor departs from the source of radiation exposure, his dose rate will be reduced. It is assumed that external exposure occurs uniformly during the year.

Internal Dose. The internal dose arises from a radiation source entering the human body through either ingestion of contaminated food and water or inhalation of contaminated air. In this PEIS, pathways for internal exposure include ingestion of crops contaminated either by airborne radiation depositing on the crops or by irrigation of crops using contaminated water sources, ingestion of animal products from animals that ingested contaminated food, ingestion of contaminated water, inhalation of contaminated air, and absorption of contaminated water through the skin during swimming. Unlike external exposures, once the radiation enters the body, it remains there for various periods of time that depend on decay and biological elimination rates. The unit of measure for internal doses is the committed dose equivalent. It is the internal dose that each body organ receives from 1 "year intake" (ingestion plus inhalation). Normally, a 50- or 70-year dose-commitment period is used (i.e., the 1 year intake period plus 49 or 69 years). The dose rate increases during the 1 year of intake. The dose rate, after the 1 year of intake, slowly declines as the radioactivity in the body continues to produce a dose. The integral of the dose rate over the 50 or 70 years gives the committed dose equivalent. In this PEIS, a 50-year, dose-commitment period was used.

The various organs of the body have different susceptibilities to harm from radiation. The quantity that takes these different susceptibilities into account to provide a broad indicator of the risk to the health of an individual from radiation is called the committed effective dose equivalent. It is obtained by multiplying the committed dose equivalent in each major organ or tissue by a weighting factor associated with the risk susceptibility of the tissue or organ, then summing the totals. It is possible that the committed dose equivalent to an organ is larger than the committed effective dose equivalent if that organ has a small weighting factor. The concept of committed effective dose equivalent applies only to internal pathways.

Combined External and Internal Dose. For convenience, the sum of the committed effective dose equivalent from internal pathways and the effective dose equivalent from external pathways is also called the committed effective dose equivalent in this PEIS (note that in Department of Energy [DOE] Order 5400.1, this quantity is called the effective dose equivalent).

The units used in this PEIS for committed dose equivalent, effective dose equivalent, and committed effective dose equivalent to an individual are the rem and mrem (1/1000 of 1 rem). The corresponding unit for the collective dose to a population (the sum of the doses to members of the population, or the product of the number of exposed individuals and their average dose) is the person-rem.

Sources of Radiation. The average American receives a total of about 350 mrem/year (yr) from all sources of radiation, both natural and manmade. The sources of radiation can be divided into six different categories: cosmic radiation, terrestrial radiation, internal radiation, consumer products, medical diagnosis and therapy, and other sources (NCRP 1987a:9-15). Each category is discussed below.

Cosmic radiation is ionizing radiation resulting from energetic charged particles from space continuously hitting the earth's atmosphere. These particles and the secondary particles and photons they create are cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with altitude above sea level. For the sites considered in this PEIS, the cosmic radiation ranged from 27 to 50 mrem/yr. The average dose to the people in the United States is about 27 mrem/yr.

External terrestrial radiation is the radiation emitted from the radioactive materials in the earth's rocks and soils. The average dose from external terrestrial radiation is about 28 mrem/yr. The external terrestrial radiation for the sites in this PEIS ranged from 15 to 63 mrem/yr.

Internal radiation arises from the human body metabolizing natural radioactive material which has entered the body by inhalation or ingestion. Natural radionuclides in the body include isotopes of U, thorium, radium, radon, polonium, bismuth, potassium, rubidium, and carbon. The major contributor to the annual dose equivalent for internal radioactivity are the short-lived decay products of radon which contribute about 200 mrem/yr. The average dose from other internal radionuclides is about 39 mrem/yr.

Consumer products also contain sources of ionizing radiation. In some products, like smoke detectors and airport x ray machines, the radiation source is essential to the products' operation. In other products, such as television and tobacco, the radiation occurs incidentally to the product function. The average dose is about 10 mrem/yr.

Radiation is an important diagnostic medical tool and cancer treatment. Diagnostic x rays result in an average exposure of 39 mrem/yr. Nuclear medical procedures result in an average exposure of 14 mrem/yr.

There are a few additional sources of radiation that contribute minor doses to individuals in the United States. The dose from nuclear fuel cycle facilities such as uranium mines, mills and fuel processing plants, nuclear power plants and transportation routes has been estimated to be less than 1 mrem per year. Radioactive fallout from atmospheric atomic bomb tests, emissions of radioactive material from DOE and Nuclear Regulatory Commission (NRC) licensed facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials contributes less than 1 mrem/yr to the average dose to an individual. Air travel contributes approximately 1 mrem/yr to the average dose.

The collective (or population) dose to an exposed population is calculated by summing the estimated doses received by each member of the exposed population. This total dose received by the exposed population is measured in person-rem. For example, if 1,000 people each received a dose of 1 mrem (0.001 rem), the collective dose is 1,000 persons x 0.001 rem = 1.0 person-rem. Alternatively, the same collective dose (1.0 person-rem) results from 500 people each of whom received a dose of 2 mrem (500 persons x 2 mrem = 1 person-rem).

Limits of Radiation Exposure. The amount of manmade radiation that the public may be exposed to is limited by Federal regulations. Although most scientists believe that radiation absorbed in small doses over several years is not harmful, U.S. Government regulations assume that the effects of all radiation exposures are cumulative.

Under the *Clean Air Act*, the exposure to a member of the general public from DOE facility releases into the atmosphere is limited by the Environmental Protection Agency (EPA) to a dose of 10 mrem/yr in addition to the natural background and medical radiation normally received (40 Code of Federal Regulations [CFR] 61, Subpart H). DOE also limits to 10 mrem the dose annually received from material released to the atmosphere (DOE Order 5400.5). The EPA and DOE also limit the annual dose to a member of the general public from radioactive releases to drinking water to 4 mrem, as required under the *Safe Drinking Water Act* (40 CFR 141; DOE Order 5400.5). The annual dose from all radiation sources from a site is limited by the EPA to 25 mrem (40 CFR 190). The DOE annual limit of radiation dose to a member of the general public from all DOE facilities is 100 mrem total, from all pathways (DOE Order 5400.5).

All DOE facilities covered by this PEIS operate well below this limit. It is estimated that the average individual in the United States receives a dose of about 0.3 rem (300 mrem) per year from natural sources of radiation. For perspective, a modern chest x ray results in an approximate dose of 0.006 rem (6 mrem), while a diagnostic pelvis and hip x ray results in an approximate dose of 0.065 rem (65 mrem) (NCRP 1987a:45). A person must receive an acute (short-term) dose of approximately 600 rem (600,000 mrem) before there is a high probability of near-term death (NAS 1990a:176).

For people working in an occupation that involves radiation, DOE and the NRC limit doses to 5 rem (5,000 mrem) in any 1 year (10 CFR 20; 10 CFR 835). For NRC-licensed facilities, the applicable site dose limits depend on the facility type. For other-than-power-reactors, the EPA limits discussed above apply. For power reactors, the annual total dose limit from all releases combined is the same as the EPA limit of 25 mrem (40 CFR 190). However, to demonstrate compliance with the as low as reasonably achievable philosophy, efforts must be made to further reduce releases to the guideline values given in Appendix I to 10 CFR 50.

M.2.1.2 Health Effects

Radiation exposure and its consequences are topics of interest to the general public. For this reason, this PEIS places much emphasis on the consequences of exposure to radiation, even though the effects of radiation exposure under most circumstances evaluated in this PEIS are small. This section explains the basic concepts used in the evaluation of radiation effects in order to provide the background for later discussion of impacts.

Radiation can cause a variety of ill-health effects in people. The most significant ill-health effect to depict the consequences of environmental and occupational radiation exposure is induction of cancer fatalities. This effect is referred to as "latent" cancer fatalities because the cancer may take many years to develop and for death to occur and may not actually be the cause of death. In the discussions which follow, it should be noted that all fatal cancers are latent and the term "latent" is not used.

Health impacts from radiation exposure, whether from sources external or internal to the body, generally are identified as "somatic" (affecting the individual exposed) or "genetic" (affecting descendants of the exposed individual). Radiation is more likely to produce somatic effects rather than genetic effects. Therefore, for this PEIS, only the somatic risks are presented. The somatic risks of most importance are the induction of cancers. Except for leukemia, which can have an induction period (time between exposure to carcinogen and cancer diagnosis) of as little as 2 to 7 years, most cancers have an induction period of more than 20 years.

For a uniform irradiation of the body, the incidence of cancer varies among organs and tissues; the thyroid and skin demonstrate a greater sensitivity than other organs. However, such cancers also produce relatively low mortality rates because they are relatively amenable to medical treatment. Because of the readily available data for cancer mortality rates and the relative scarcity of prospective epidemiologic studies, somatic effects leading to cancer fatalities rather than cancer incidence are presented in this PEIS. The numbers of cancer fatalities can be used to compare the risks among the various alternatives.

The fatal cancer risk estimators presented in this appendix for radiation technically apply only to low-linear energy transfer radiation (gamma rays and beta particles). However, on a per rem rather than a per rad basis, the fatal risk estimators are higher for this type of radiation than for high-linear energy transfer radiation (alpha particles). In this PEIS, the low-linear energy transfer risk estimators are conservatively assumed to apply to all radiation exposures.

The National Research Council's Committee on the Biological Effects of Ionizing Radiations (BEIR) has prepared a series of reports to advise the U.S. Government on the health consequences of radiation exposures. The latest of these reports, *Health Effects of Exposure to Low Levels of Ionizing Radiation BEIR V*, published in 1990, provides the most current estimates for excess mortality from leukemia and cancers other than leukemia expected to result from exposure to ionizing radiation. The BEIR V report updates the models and risk estimates provided in the earlier report of the BEIR III Committee, *The Effects of Populations of Exposure to Low-Levels of Ionizing Radiation*, published in 1980. The BEIR V models were developed for application to the U.S. population.

The BEIR V provides estimates that are consistently higher than those in BEIR III. This is attributed to several factors including the use of a linear dose response model for cancers other than leukemia, revised dosimetry for the Japanese atomic bomb survivors, and additional follow-up studies of the atomic bomb survivors and other cohorts. The BEIR III employs constant relative and absolute risk models, with separate coefficients for each of several sex and age-at-exposure groups, while BEIR V develops models in which the excess relative risk is expressed as a function of age at exposure, time after exposure, and sex for each of several cancer categories. The BEIR III models were based on the assumption that absolute risks are comparable between the atomic bomb survivors and the U.S. population, while BEIR V models were based on the assumption that the relative risks are comparable. For a disease such as lung cancer, where baseline risks in the United States are much larger than those in Japan, the BEIR V approach leads to larger risk estimates than the BEIR III approach.

The models and risk coefficients in BEIR V were derived through analyses of relevant epidemiologic data including the Japanese atomic bomb survivors, ankylosis spondylitis patients, Canadian and Massachusetts fluoroscopy patients (breast cancer), New York postpartum mastitis patients (breast cancer), Israel Tinea Capitis patients (thyroid cancer), and Rochester thymus patients (thyroid cancer). Models for leukemia, respiratory cancer, digestive cancer, and other cancers used only the atomic bomb survivor data, although results of analyses of the ankylosis spondylitis patients were considered. Atomic bomb survivor analyses were based on revised dosimetry with an assumed Relative Biological Effectiveness of 20 for neutrons, and were restricted to doses less than 400 rads. Estimates of risks of fatal cancers other than leukemia were obtained by totaling the estimates for breast cancer, respiratory cancer, digestive cancer and other cancers.

Risk Estimates for Doses Received During an Accident. The BEIR V includes risk estimates for a single exposure of 10 rem to a population of 100,000 people (1.0×10^6 person-rem). In this case, fatality estimates for leukemia, breast cancer, respiratory cancer, digestive cancer, and other cancers are given for both sexes and nine age-at-exposure groups. These estimates, based on the linear model, are summarized in Table M.2.1.2–1. The average risk estimate from all ages and both sexes is 885 excess cancer fatalities per million person-rem. This value has been conservatively rounded up to 1,000 excess cancer fatalities per million person-rem. Section M.5.1.3.2 contains additional discussions on accident risk estimators.

Although values for other health effects are not presented in this PEIS, the risk estimators for non-fatal cancers and for genetic disorders to future generations are estimated to be approximately 200 and 260 per million person-rem, respectively. These values are based on information presented in the *1990 Recommendations of the International Commission on Radiological Protection* (ICRP Publication 60) and are seen to be 20 percent and 26 percent, respectively, of the fatal cancer estimator. Thus, for example, if the number of excess fatal cancers is projected to be "X," the number of excess genetic disorders would be 0.26 times "X."

Risk Estimates for Doses Received During Normal Operation. For low doses and dose rates, a linear-quadratic model was found to provide a significantly better fit to the data for leukemia than a linear one, and leukemia risks were based on a linear-quadratic function. This reduces the effects by a factor of two over estimates that are obtained from the linear model. For other cancers, linear models were found to provide an adequate fit to the data, and were used for extrapolation to low doses. However, the BEIR V Committee recommended reducing these linear estimates by a factor between 2 and 10 for doses received at low dose rates. For this PEIS, a risk reduction factor of two was adopted for conservatism.

Table M.2.1.2–1. Lifetime Risks per 100,000 Persons Exposed to a Single Exposure of 10 rem

	Type of Fatal Cancer		
Gender	**Leukemia[a]**	**Cancers Other Than Leukemia**	**Total Cancers**
Male	220	660	880
Female	160	730	890
Average	**190**	**695**	**885[b]**

[a] These are the linear estimates, and are double the linear-quadratic estimates provided in BEIR V for leukemia at low doses and dose-rates.

[b] This value has been rounded up to 1,000 excess cancer fatalities per million person-rem.

Source: NAS 1990a.

Based on the above discussion, the resulting risk estimator would be equal to half the value observed for accident situations or approximately 500 excess fatal cancer per million person-rem (0.0005 excess fatal cancer per person-rem). This is the risk value used in this PEIS to calculate fatal cancers to the general public during normal operations. For workers, a value of 400 excess fatal cancers per million person-rem (0.0004 excess fatal cancer per person-rem) is used in this PEIS. This lower value reflects the absence of children (who are more radiosensitive than adults) in the workforce. Again, based on information provided in the *1990 Recommendations of the International Commission of Radiological Protection* (ICRP Publication 60), the health risk estimators for nonfatal cancer and genetic disorders among the public are 20 percent and 26 percent, respectively, of the fatal cancer risk estimator. For workers they are both 20 percent of the fatal cancer risk estimator. For this PEIS, only fatal cancers are presented.

The risk estimates may be applied to calculate the effects of exposing a population to radiation. For example, in a population of 100,000 people exposed only to natural background radiation (0.3 rem/yr), 15 latent cancer fatalities per year would be inferred to be caused by the radiation (100,000 persons x 0.3 rem/yr x 0.0005 latent cancer fatalities per person-rem = 15 latent cancer fatalities/yr).

Sometimes, calculations of the number of excess cancer fatalities associated with radiation exposure do not yield whole numbers and, especially in environmental applications, may yield numbers less than 1.0. For example, if a population of 100,000 were exposed as above, but to a total dose of only 0.001 rem, the collective dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons x 0.001 rem x 0.0005 latent cancer fatalities/person-rem = 0.05 latent fatal cancers).

For latent cancer fatalities less than 1.0, the estimated 0.05 latent cancer fatalities is interpreted as a statistical estimate. That is, 0.05 is the *average* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people. In most groups, no person (0 people) would incur a latent cancer fatality from the 0.001 rem dose each member would have received. In a small fraction of the groups, 1 latent fatal cancer would result; in exceptionally few groups, 2 or more latent fatal cancers would occur. The

average number of deaths over all the groups would be 0.05 latent fatal cancers (just as the average of 0, 0, 0, and 1 is 1/4, or 0.25). The most likely outcome is 0 latent cancer fatalities.

These same concepts apply to estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The "number of latent cancer fatalities" corresponding to a single individual's exposure over a (presumed) 72-year lifetime to 0.3 rem/yr is the following:

1 person x 0.3 rem/year x 72 years x 0.0005 latent cancer fatalities/person-rem = 0.011 latent cancer fatalities.

Again, this should be interpreted in a statistical sense; that is, the estimated effect of background radiation exposure on the exposed individual would produce a 1.1-percent chance that the individual might incur a latent fatal cancer caused by the exposure over his full lifetime. Presented another way, this method estimates that approximately 1.1 percent of the population might die of cancers induced by the radiation background.

M.2.2 METHODOLOGY FOR ESTIMATING RADIOLOGICAL IMPACTS OF NORMAL OPERATION

The radiological impacts of normal operation of reactors and support facilities were calculated using Version 1.485 of the GENII computer code. Site-specific and technology-specific input data were used, including location, meteorology, population, food production and consumption, and source terms. [Text deleted.] Section M.2.2.1 briefly describes GENII and outlines the approach used for normal operations. The approach used for design basis accidents is discussed in Section M.5 of this appendix.

M.2.2.1 GENII Computer Code

The GENII computer model, developed by Pacific Northwest Laboratory for DOE, is an integrated system of various computer modules which analyze environmental contamination resulting from acute or chronic releases to, or initial contamination in, air, water, or soil. The model calculates radiation doses to individuals and populations. The GENII computer model is well documented for assumptions, technical approach, methodology, and quality assurance issues (GENII—The Hanford Environmental Radiation Dosimetry Software System, December 1988). The GENII computer model has gone through extensive quality assurance and quality control steps. These include the comparison of results from model computations against those from hand calculations, and the performance of internal and external peer reviews. Recommendations given in these reports were incorporated into the final GENII computer model, as deemed appropriate.

For this PEIS only the ENVIN, ENV, and DOSE computer modules were used. The codes are connected through data transfer files. The output of one code is stored in a file that can be used by the next code in the system. In addition, a computer code called CREGENII was prepared to aid and assist the user with the preparation of input files into GENII.

CREGENII. The CREGENII code helps the user, through a series of interactive menus and questions, to prepare a text input file for the environmental dosimetry programs. In addition, CREGENII prepares a batch processing file to manage the file handling needed to control the operations of subsequent codes and to prepare an output report.

ENVIN. The ENVIN module of the GENII code controls the reading of the input files prepared by CREGENII and organizes the input for optimal use in the environmental transport and exposure module, ENV. The ENVIN code interprets the basic input, reads the basic GENII data libraries and other optional input files, and organizes the input into sequential segments on the basis of radionuclide decay chains.

A standardized file that contains scenario, control, and inventory parameters is used as input to ENVIN. Radionuclide inventories can be entered as functions of releases to air or water, concentrations in basic environmental media (air, soil, or water), or concentrations in foods. If certain atmospheric dispersion options have been selected, this module can generate tables of atmospheric dispersion parameters that will be used in later calculations. If the finite plume air submersion option is requested in addition to the atmospheric dispersion calculations, preliminary energy-dependent finite plume dose factors also are prepared. The ENVIN module prepares the data transfer files that are used as input by the ENV module; ENVIN generates the first portion of the calculation documentation—the run input parameters report.

ENV. The ENV module calculates the environmental transfer, uptake, and human exposure to radionuclides that result from the chosen scenario for the user specified source term. The code reads the input files from ENVIN and then, for each radionuclide chain, sequentially performs the precalculations to establish the conditions at the start of the exposure scenario. Environmental concentrations of radionuclides are established at the beginning of the scenario by assuming decay of preexisting sources, considering biotic transport of existing subsurface contamination, and defining soil contamination from continuing atmospheric or irrigation depositions. Then, for each year of postulated exposure, the code estimates air, surface soil, deep soil, groundwater, and surface water concentrations of each radionuclide in the chain. Human exposures and intakes of each radionuclide are calculated for: 1) pathways of external exposure from finite atmospheric plumes; 2) inhalation; 3) external exposure from contaminated soil, sediments, and water; 4) external exposure from special geometries; and 5) internal exposures from consumption of terrestrial foods, aquatic foods, drinking water, animal products, and inadvertent intake of soil. The intermediate information on annual media concentrations and intake rates are written to data transfer files. Although these may be accessed directly, they are usually used as input to the DOSE module of GENII.

DOSE. The DOSE module reads the annual intake and exposure rates defined by the ENV module and converts the data to radiation dose. External dose is calculated with precalculated factors from the EXTDF module or from a data file prepared outside of GENII. Internal dose is calculated with precalculated factors from the INTDF module.

EXTDF. The EXTDF module calculates the external dose-rate factors for submersion in an infinite cloud of radioactive materials, immersion in contaminated water, and direct exposure to plane or slab sources of radionuclides. EXTDF was not used. Instead, the dose rate factors listed in *External Dose Rate Factors for Calculation of Dose to the Public* (DOE/EH-0070) were used for this PEIS.

INTDF. Using the *Limits for Intakes of Radionuclides by Workers* (ICRP Publication 30) model, the INTDF module calculates the internal (inhalation and ingestion) dose conversion factors of radionuclides for specific organs. The factors generated by INTDF were used for the calculations presented in this PEIS.

GENII is a general purpose computer code used to model dispersion, transport, and long-term exposure effects of specific radionuclides and pathways. Sophisticated codes such as UFOTRI and ETMOD (Environmental Tritium Model) are used exclusively for modelling tritium transport and dosimetry. The UFOTRI and ETMOD codes were not chosen for use in this PEIS due to the lack of information on detailed facility design and on the breakdown of tritium into elemental and tritiated water forms, and because these codes cannot be used for modeling the exposure effects of radionuclides other than tritium. GENII was chosen because it can model both air and surface transport pathways and is not restricted to any radionuclides.

M.2.2.2 Data and Assumptions

In order to perform the dose assessments for this PEIS, different types of data must be collected and/or generated. In addition, calculational assumptions have to be made. This section discusses the data collected and/or generated for use in the dose assessment and assumptions made for this PEIS.

Meteorological Data. The meteorological data used for all sites were in the form of joint frequency data files. A joint frequency data file is a table listing the fractions of time the wind blows in a certain direction, at a certain speed, and within a certain stability class. The joint frequency data files were based on measurements over a 1-year period at various locations and at different heights at the sites. Average meteorological conditions (averaged over the 1-year period) were used for normal operation. Meteorological data are presented in Health Risk Data, October 1996.

Population Data. Population distributions were based on *1990 Census of Population and Housing* data. Projections were determined for 2030 (approximate midlife of operations) for areas within 80 km (50 mi) of the proposed facilities at each candidate site. The site population in 2030 was assumed to be representative of the population over the operational period evaluated, and was used in the impact assessments. The population was spatially distributed on a circular grid with 16 directions and 10 radial distances up to 80 kilometers. The grid was centered on the facility from which the radionuclides were assumed to be released. Population data are presented in Health Risk Data, October 1996.

Source Term Data. The source terms (quantities of radionuclides released to the environment over a given period) were estimated on the basis of latest conceptual designs of facilities and experience with similar facilities. The source terms used to generate the estimated impacts of normal operation are provided in Section M.2.3 for the storage and disposition facilities which could be located at the various sites. Source terms for candidate and representative sites are presented in Sections M.2.4 through M.2.15.

Food Production and Consumption Data. Data from the *1987 Census of Agriculture* was used to generate site-specific data for food production. Food production was spatially distributed on the same circular grid as was used for the population distributions. The consumption rates were those used in GENII for the maximum individual and average individual. People living within the 80 km (50 mi) assessment area were assumed to consume only food grown in that area.

Calculational Assumptions. Dose assessments were performed for members of the general public and workers. Dose assessments for members of the public were performed for two different types of receptors considered in this PEIS: a maximally exposed offsite individual and the general population living within 80 km (50 mi) of the facility. It was assumed that the maximally exposed individual (MEI) was located at a position on the site boundary that would yield the highest impacts during normal operation of a given alternative. If more than one facility was assumed to be operating at a site, the dose to a "maximum receptor" (that is, a potential site MEI) from each facility was calculated. This was accomplished by preliminarily designating each potential MEI as a maximum receptor for each facility modeled—subsequently, whichever maximum receptor was found to incur the largest dose was then ultimately selected as the MEI for the site. An 80-km (50-mi) population dose was calculated for each operating facility at a site. These doses were then added to give the total population dose at that site.

To estimate the radiological impacts from normal operation of reactors and support facilities, additional assumptions and factors were considered in using GENII, as follows:

- No prior deposition of radionuclides on ground surfaces was assumed.
- For the maximally exposed off-site individual, the annual exposure time to the plume and to soil contamination was 0.7 year (NRC 1977b:1.109-68).
- For the population, the annual exposure time to the plume and to soil contamination was 0.5 year (NRC 1977b:1.109-68).
- The exposed individual or population was assumed to have the characteristics and habits (for example; inhalation and ingestion rates) of the adult human.

- A semi-infinite/finite plume model was used for air immersion doses. Other pathways evaluated were ground exposure, inhalation, ingestion of food crops and animal products contaminated by either deposition of radioactivity from the air or irrigation, ingestion of fish and other aquatic food raised in contaminated water, swimming and boating in contaminated surface water, and drinking contaminated water. It should be noted that not all pathways were available at every site.

- For atmospheric releases it was assumed that ground level releases would occur for all storage and disposal facilities. For site dependent facilities, reported release heights were used and assumed to be the effective stack height. Use of the effective stack height negates plume rise thereby making the resultant doses conservative.

- The calculated doses were 50-year committed doses from 1 year of intake.

The exposure, uptake, and usage parameters used in the GENII model are provided in Tables M.2.2.2–1 through M.2.2.2–4.

Annual average doses to workers for No Action at the Hanford Site (Hanford), Nevada Test Site (NTS), Idaho National Engineering Laboratory (INEL), Pantex Plant (Pantex), Rocky Flats Environmental Technology Site (RFETS), and Los Alamos National Laboratory (LANL) were generally based on measured values received by radiation workers during the 1989 to 1992 time period. The dose values are given in a series of documents that cover this time period. Dose values for 1992 are contained in "Compilation of Doses to Workers at DOE Facilities in 1992" (DOE 1993n:7). The same type reports are used for the earlier years. The average dose received by a worker at these sites in 2005 was assumed to remain the same as the annual average during the 1989 to 1992 period. The total workforce dose in 2005 was calculated by multiplying the average worker dose by the projected number of workers in 2005. For Oak Ridge Reservation (ORR) and Savannah River Site (SRS), worker dose projections provided by the sites were used. For NRC-licensed sites, No Action worker doses were based on reported values for 1993 given in *Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities, 1993* (NUREG-0713-V15).

Doses to workers directly associated with storage and disposition facilities were taken from the reports prepared by Fluor Daniel, Inc.; Sandia National Laboratories (SNL), New Mexico; LANL; Lawrence Livermore National Laboratory (LLNL); and SRS. To obtain the total workforce dose at a site with a particular storage or disposition facility in operation, the site dose from No Action was added to that from the storage or disposition facility being evaluated. The average dose to a site worker was then calculated by dividing this dose by the total number of radiation workers at the site.

All doses to workers include a component associated with the intake of radioactivity into the body and another component resulting from external exposure to direct radiation.

A more detailed discussion of doses to workers associated with storage and disposition is given in Section M.2.3.2.

M.2.2.3 Health Effects Calculations

In this PEIS, the collective combined effective dose equivalent is the sum of the collective committed effective dose equivalent (internal dose) and the collective effective dose equivalent (external dose), as explained in Section M.2.1.1. Doses calculated by GENII were used to estimate health effects using the risk estimators presented in Section M.2.1.2. The incremental cancer fatalities in the general population and groups of workers due to radiation exposure were therefore estimated by multiplying the collective combined effective dose equivalent by 0.0005 and 0.0004 fatal cancers/person-rem, respectively.Although health risk factors are statistical factors and therefore not strictly applicable to individuals, they have been used in the past to estimate the incremental risk to an individual from exposure to radiation. Therefore, the factor of 0.0005 and 0.0004

Table M.2.2.2-1. GENII Exposure Parameters to Plumes and Soil Contamination

Maximum Individual				General Population			
External Exposure		Inhalation of Plume		External Exposure		Inhalation of Plume	
Plume (hours)	Soil Contamination (hours)	Exposure Time (hours)	Breathing Rate (cm^3/sec)	Plume (hours)	Soil Contamination (hours)	Exposure Time (hours)	Breathing Rate (cm^3/sec)
6,136	6,136	6,136	270	4,383	4,383	4,383	270

Source: HNUS 1996a.

Table M.2.2.2-2. GENII Usage Parameters for Consumption of Terrestrial Food

	Maximum Individual				General Population			
Food Type	Growing Time (days)	Yield (kg/m^2)	Holdup Time (days)	Consumption Rate (kg/yr)	Growing Time (days)	Yield (kg/m^2)	Holdup Time (days)	Consumption Rate (kg/yr)
Leafy Vegetables	90.0	1.5	1.0	30.0	90.0	1.5	14.0	15.0
Root Vegetables	90.0	4.0	5.0	220.0	90.0	4.0	14.0	140.0
Fruit	90.0	2.0	5.0	330.0	90.0	2.0	14.0	64.0
Grains/Cereals	90.0	0.8	180.0	80.0	90.0	0.8	180.0	72.0

Source: HNUS 1996a.

Table M.2.2.2–3. GENII Usage Parameters for Consumption of Animal Products

	Maximum Individual									
			Stored Feed				Fresh Forage			
Food Type	**Consumption Rate (kg/yr)**	**Holdup Time (days)**	**Diet Fraction**	**Growing Time (days)**	**Yield (kg/m^2)**	**Storage Time (days)**	**Diet Fraction**	**Growing Time (days)**	**Yield (kg/m^2)**	**Storage Time (days)**
Beef	80.0	15.0	0.25	90.0	0.80	180.0	0.75	45.0	2.00	100.0
Poultry	18.0	1.0	1.00	90.0	0.80	180.0				
Milk	270.0	1.0	0.25	45.0	2.00	100.0	0.75	30.0	1.50	0
Eggs	30.0	1.0	1.00	90.0	0.80	180.0				
	General Population									
Beef	70.0	34.0	0.25	90.0	0.80	180.0	0.75	45.0	2.00	100.0
Poultry	8.5	34.0	1.00	90.0	0.80	180.0				
Milk	230.0	4.0	0.25	45.0	2.00	100.0	0.75	30.0	1.50	0
Eggs	20.0	18.0	1.00	90.0	0.80	180.0				

Source: HNUS 1996a.

Table M.2.2.2–4. GENII Usage Parameters for Aquatic Activities

	Maximum Individual			General Population		
Activity	**Transit Time to Usage Point (days)**	**Holdup Time (days)**	**Usage Rate (per year)**	**Transit Time to Usage Point (days)**	**Holdup Time (days)**	**Usage Rate**
Drinking water	0	0	730 liters	0	0	Site dependent
Swimming	0	0	100 hours	0	0	Site dependent
Boating	0	0	100 hours	0	0	Site dependent
Shoreline	0	0	500 hours	0	0	Site dependent
Ingestion of fish	0	0	40 kg	0	0	Site dependent
Ingestion of molluscs	0	0	6.9 kg	0	0	Site dependent
Ingestion of crustacea	0	0	6.9 kg	0	0	Site dependent
Ingestion of plants	0	0	6.9 kg	0	0	Site dependent

Source: HNUS 1996a.

per rem of individual committed effective dose equivalent for a member of the public and for a worker, respectively, have also been used in this PEIS to calculate the individual's incremental fatal cancer risk from exposure to radiation.

For the public, the health effects expressed in this PEIS are the risk of fatal cancers to the maximally exposed individual and the number of fatal cancers to the 80-km (50-mi) population from exposure to radioactivity released from any site over the full operational period. For workers, the health effects expressed are the risk to the average worker at a site and the number of fatal cancers to all workers at that site over the full period of site operations.

M.2.3 STORAGE AND DISPOSITION FACILITIES INFORMATION

This section presents compilations of radiological releases to the environment from facilities associated with all alternatives assessed in this PEIS except No Action. The No Action releases are presented as part of the specific site discussions in Section M.2.4 through M.2.9. This section also presents the in-plant worker doses associated with these same facilities.

M.2.3.1 Radiological Releases to the Environment

Long-Term Storage. The annual release of radioactivity to the environment associated with the alternatives for the long-term storage of Pu and highly enriched uranium (HEU) are given in Table M.2.3.1–1. The releases, by radionuclide, are given for operation of upgraded Pu storage facilities at Hanford, INEL, Pantex, and SRS and upgraded HEU storage facilities at ORR; for operation of consolidated Pu storage facilities at Hanford, NTS, INEL, Pantex, and SRS; and for operation of collocated Pu and HEU storage facilities at Hanford, NTS, INEL, Pantex, ORR, and SRS.

Front-End Processes Common to Multiple Plutonium Disposition Alternatives. The annual releases of radioactivity to the environment associated with front-end processes common to multiple Pu disposition alternatives are given in Table M.2.3.1–2. The releases, by radionuclide, include those for operation of a pit disassembly/conversion facility, a Pu conversion facility, and a mixed oxide (MOX) fuel fabrication facility. These releases are independent of site location.

Table M.2.3.1–1. Annual Radioactive Releases During Normal Operation of Long-Term Storage Facilities (curies)[a]

Facility/Radionuclides	Site			
Upgraded Pu Storage Facility	**Hanford**	**INEL**	**Pantex**	**SRS**
Pu-238	$1.8x10^{-8}$	$2.5x10^{-9}$	b	c
Pu-239	$5.6x10^{-8}$	$9.2x10^{-8}$	b	c
Pu-240	$2.8x10^{-8}$	$2.4x10^{-8}$	b	c
Pu-241	$8.6x10^{-7}$	$8.6x10^{-8}$	b	c
Pu-242	$1.6x10^{-11}$	$3.6x10^{-12}$	b	c
Am-241	$3.5x10^{-8}$	$4.5x10^{-10}$	b	c
Upgraded HEU Storage Facility	**ORR[d]**			
U-234	$2.7x10^{-12}$			
U-235	$4.7x10^{-11}$			
U-236	$2.9x10^{-10}$			
U-238	$9.3x10^{-9}$			
Consolidated Pu Storage Facility	**Hanford, NTS, INEL, Pantex, and SRS**			
Pu-238	$1.5x10^{-8}$			
Pu-239	$5.4x10^{-7}$			
Pu-240	$1.4x10^{-7}$			
Pu-241	$5.1x10^{-7}$			
Pu-242	$2.1x10^{-11}$			
Am-241	$2.7x10^{-9}$			

Table M.2.3.1–1. Annual Radioactive Releases During Normal Operation of Long-Term Storage Facilities (curies)[a] —Continued

Facility/Radionuclides	Site
Collocated Pu and HEU Storage Facility	**Hanford, NTS, INEL, Pantex, ORR, and SRS**
Pu-238	1.5×10^{-8}
Pu-239	5.4×10^{-7}
Pu-240	1.4×10^{-7}
Pu-241	5.1×10^{-7}
Pu-242	2.1×10^{-11}
Am-241	2.7×10^{-9}
U-234	2.7×10^{-12}
U-235	4.7×10^{-11}
U-236	2.9×10^{-10}
U-238	9.3×10^{-9}

[a] All releases are to the atmosphere.
[b] Radiation dose for the storage facility is calculated to be 1.8×10^{-8} for the MEI and 6.3×10^{-6} person-rem for the population within 80 km, but no radionuclide emissions are available (HNUS 1996a).
[c] Radiation dose for the storage facility is calculated to be 8.3×10^{-6} for the MEI and 3.5×10^{-4} person-rem for the population within 80 km, but no radionuclide emissions are available (SR DOE 1995e).
[d] Assumed uranium releases from Collocated Storage Facility would be applicable for the ORR Upgraded HEU Storage Facility.
Note: Am=Americium.
Source: DOE 1996e; DOE 1996f; HF 1995a:1; HNUS 1996a; IN DOE 1996a; PX MH 1995a; SRS 1996a:4.

Plutonium Disposition Alternatives. The annual releases of radioactivity to the environment associated with the Pu disposition alternatives are given in Table M.2.3.1–3 for facilities other than reactors, and in Tables M.2.3.1–4 and M.2.3.1–5 for reactors. The releases have been separated to facilitate data presentation since reactors release a much larger number of radionuclides than do the other facilities. Table M.2.3.1–3 presents the releases by radionuclide for operation of ceramic immobilization, vitrification, and the deep borehole complex. Tables M.2.3.1–4 and M.2.3.1–5 present the releases, by radionuclide, for operation of a large and a small evolutionary light water reactor (LWR), respectively.

M.2.3.2 Radiological Impacts to In-Plant Workers

Operation of each of the facilities whose releases were addressed in Section M.2.3.1 result in radiological doses and associated health effects to in-plant workers. The numbers of badged workers, the average and total worker doses, and the risks and numbers of fatal cancers are given in Table M.2.3.2–1 for workers involved with disposition activities. It should be noted that for several disposition facilities, the number of years for facility operation varies due to the fact that the duration of operation depends on the end use of that facility. For example, the MOX fuel fabrication facility could operate for either 17 years supplying fuel for evolutionary and partially completed U.S. reactors or 23 years supplying fuel for existing Canadian Deuterium Uranium reactors.

Based on a review of impacts to workers involved in similar operations, the radiological impacts to workers involved with storage activities assume an annual average dose of approximately 250 mrem per worker for the storage upgrade alternative (HF DOE 1996a:2-4; IN DOE 1996a:1-6; NT DOE 1996a:1-7. For the upgrade at Pantex, an average measurable dose of 116 mrem/yr to radiological workers was assumed to be applicable for the workers associated with storage operations (PX 1996e:2). The number of these involved workers, and therefore the total dose to the involved workforce, is site dependent. For consolidated and collocation storage alternatives that require new facilities, the annual average dose is estimated to be 258 mrem and 264 mrem per worker, respectively. For these storage facilities, the number of involved badged workers are independent of the site and would number 92 and 95, respectively; therefore, the total dose to the involved workforce is also site independent (DOE 1996e:1-6; DOE 1996f:1-8). The detailed results of worker doses associated with all storage facilities are presented in the storage public and occupational health sections of Chapter 4.

Table M.2.3.1–2. ***Annual Radioactive Releases During Normal Operation of Facilities for Plutonium Disposition Used by Multiple Alternatives (curies)***[a]

Facility/Radionuclides	Releases
Pit Disassembly/Conversion Facility	
Pu-238	4.2×10^{-7}
Pu-239	4.3×10^{-5}
Pu-240	1.0×10^{-5}
Pu-241	3.2×10^{-5}
Pu-242	2.9×10^{-10}
Am-241	1.7×10^{-5}
Pu Conversion Facility	
Pu-238	2.3×10^{-6}
Pu-239	3.6×10^{-5}
Pu-240	1.2×10^{-5}
Pu-241	4.8×10^{-5}
Pu-242	3.8×10^{-9}
Am-241	2.6×10^{-7}
Mixed Oxide Fuel Fabrication Facility	
Pu-238	7.9×10^{-7}
Pu-239	2.9×10^{-5}
Pu-240	7.6×10^{-6}
Pu-241	2.7×10^{-5}
Pu-242	1.1×10^{-9}
Am-241	1.4×10^{-7}
U-232	1.3×10^{-7}
U-234	3.2×10^{-8}
U-235	6.2×10^{-10}
U-238	4.8×10^{-8}

[a] All releases are to the atmosphere.

Note: Am=Americium.

Source: HNUS 1996a; LANL 1996b; LANL 1996c; LANL 1996d.

Table M.2.3.1–3. Annual Radioactive Releases During Normal Operation of Non-Reactor Plutonium Disposition Facilities (curies)[a]

Facility/Radionuclides	Releases
Borehole Complex (Direct Disposition Alternative)	
Pu-238	$1.2x10^{-11}$
Pu-239	$9.2x10^{-10}$
Pu-240	$2.4x10^{-10}$
Pu-241	$1.3x10^{-10}$
Pu-242	$3.6x10^{-14}$
Am-241	$2.0x10^{-10}$
Ceramic Immobilization Facility (Immobilized Disposition Alternative)	
Pu-238	$9.3x10^{-11}$
Pu-239	$7.0x10^{-9}$
Pu-240	$1.9x10^{-9}$
Pu-241	$9.7x10^{-10}$
Pu-242	$2.8x10^{-13}$
Am-241	$3.5x10^{-11}$
Borehole Complex (Immobilized Disposition Alternative)	
Pu-238	$1.4x10^{-11}$
Pu-239	$1.1x10^{-9}$
Pu-240	$2.8x10^{-10}$
Pu-241	$1.5x10^{-10}$
Pu-242	$4.1x10^{-14}$
Am-241	$3.0x10^{-10}$
Vitrification Alternative	
Pu-238	$3.7x10^{-8}$
Pu-239	$2.8x10^{-6}$
Pu-240	$7.5x10^{-7}$
Pu-241	$3.9x10^{-7}$
Pu-242	$1.1x10^{-10}$
Am-241	$1.4x10^{-8}$
Cs-137	$5.0x10^{-5}$
Ceramic Immobilization Alternative	
Pu-238	$9.3x10^{-11}$
Pu-239	$7.0x10^{-9}$
Pu-240	$1.9x10^{-9}$
Pu-241	$9.7x10^{-10}$
Pu-242	$2.8x10^{-13}$
Am-241	$3.5x10^{-11}$
Cs-137	$1.0x10^{-5}$

[a] All releases are to the atmosphere.

Note: Am=Americium.

Source: HNUS 1996a; LLNL 1996a; LLNL 1996c; LLNL 1996d; LLNL 1996e; LLNL 1996h.

Table M.2.3.1–4. Annual Liquid and Atmospheric Radioactive Releases From the Large Evolutionary Light Water Reactor Using a Mixed Oxide Core (curies)

	Release				Release		
	Wet Site[a]		Dry Site[a]		Wet Site[a]		Dry Site[a]
Isotope	Atmospheric	Liquid	Atmospheric	Isotope	Atmospheric	Liquid	Atmospheric
H-3	6.8×10^{1}	6.0×10^{1}	1.3×10^{2}	Sr-92	7.8×10^{-4}	8.0×10^{-4}	1.6×10^{-3}
C-14	9.2	1.6×10^{-4}	9.2	Y-90	1.7×10^{-5}	1.2×10^{-6}	1.9×10^{-5}
Ar-41	6.8	0	6.8	Y-91	1.5×10^{-4}	6.7×10^{-5}	2.1×10^{-4}
Kr-83m	1.4×10^{-3}	0	1.4×10^{-3}	Y-92	4.5×10^{-4}	4.3×10^{-4}	8.8×10^{-4}
Kr-85m	2.3×10^{1}	0	2.3×10^{1}	Y-93	1.0×10^{-3}	8.3×10^{-4}	1.8×10^{-3}
Kr-85	4.9×10^{2}	0	4.9×10^{2}	Zr-95	1.0×10^{-3}	7.4×10^{-4}	1.8×10^{-3}
Kr-87	2.5×10^{1}	0	2.5×10^{1}	Nb-95	1.5×10^{-3}	8.8×10^{-4}	2.4×10^{-3}
Kr-88	3.7×10^{1}	0	3.7×10^{1}	Mo-99	1.4×10^{-2}	7.9×10^{-4}	1.5×10^{-2}
Kr-89	4.0×10^{2}	0	4.0×10^{2}	Tc-99m	3.0×10^{-4}	8.0×10^{-4}	1.1×10^{-3}
Kr-90	5.4×10^{-4}	0	5.4×10^{-4}	Ru-103	6.0×10^{-4}	2.2×10^{-4}	8.3×10^{-4}
Xe-131m	8.6×10^{1}	0	8.6×10^{1}	Rh-103m	1.1×10^{-4}	9.0×10^{-6}	1.2×10^{-4}
Xe-133m	1.4×10^{-1}	0	1.4×10^{-1}	Ru-106	3.2×10^{-5}	2.9×10^{-4}	3.2×10^{-4}
Xe-133	3.8×10^{3}	0	3.8×10^{3}	Rh-106	1.9×10^{-5}	1.7×10^{-4}	1.9×10^{-4}
Xe-135m	6.8×10^{2}	0	6.8×10^{2}	Ag-110m	6.5×10^{-7}	3.3×10^{-4}	3.3×10^{-4}
Xe-135	2.2×10^{3}	0	2.2×10^{3}	Sb-124	1.7×10^{-4}	3.6×10^{-4}	5.3×10^{-4}
Xe-137	8.6×10^{2}	0	8.6×10^{2}	Te-129m	1.7×10^{-4}	1.3×10^{-5}	1.8×10^{-4}
Xe-138	7.2×10^{2}	0	7.2×10^{2}	Te-131m	9.1×10^{-5}	4.1×10^{-5}	1.3×10^{-4}
Xe-139	6.8×10^{-4}	0	6.8×10^{-4}	I-131	2.9×10^{-1}	3.5×10^{-3}	2.9×10^{-1}
Na-24	4.1×10^{-3}	2.8×10^{-3}	6.9×10^{-3}	Te-132	2.0×10^{-5}	4.3×10^{-6}	2.5×10^{-5}
P-32	9.2×10^{-4}	1.8×10^{-4}	1.1×10^{-3}	I-132	2.3	2.8×10^{-3}	2.3
Cr-51	3.5×10^{-2}	7.7×10^{-3}	4.3×10^{-2}	I-133	1.6	9.5×10^{-3}	1.6
Mn-54	4.9×10^{-3}	2.6×10^{-3}	7.5×10^{-3}	I-134	3.6	1.6×10^{-3}	3.6
Mn-56	3.5×10^{-3}	3.8×10^{-3}	7.3×10^{-3}	Cs-134	8.9×10^{-5}	3.2×10^{-3}	3.3×10^{-3}
Fe-55	6.5×10^{-3}	5.8×10^{-3}	1.2×10^{-2}	I-135	2.4	7.5×10^{-3}	2.4
Co-56	0	5.2×10^{-3}	5.2×10^{-3}	Cs-136	1.2×10^{-4}	4.7×10^{-4}	5.8×10^{-4}
Co-57	0	7.2×10^{-5}	7.2×10^{-5}	Cs-137	4.2×10^{-4}	8.2×10^{-3}	8.6×10^{-3}
Co-58	2.4×10^{-3}	9.0×10^{-5}	2.5×10^{-3}	Cs-138	1.7×10^{-4}	1.9×10^{-4}	3.6×10^{-4}
Co-60	1.1×10^{-2}	9.1×10^{-3}	2.0×10^{-2}	Cs-139	8.2×10^{-5}	0	8.2×10^{-5}
Fe-59	6.5×10^{-4}	1.0×10^{-4}	7.5×10^{-4}	Ba-140	1.2×10^{-2}	6.1×10^{-4}	1.2×10^{-2}
Ni-63	6.5×10^{-6}	1.4×10^{-4}	1.5×10^{-4}	La-140	1.6×10^{-3}	1.5×10^{-4}	1.8×10^{-3}
Cu-64	1.0×10^{-2}	7.5×10^{-3}	1.8×10^{-2}	Ce-141	8.6×10^{-3}	1.2×10^{-4}	8.8×10^{-3}
Zn-65	8.1×10^{-3}	9.0×10^{-5}	8.2×10^{-3}	Ce-144	1.3×10^{-5}	1.3×10^{-3}	1.3×10^{-3}
Rb-89	4.3×10^{-5}	4.4×10^{-5}	8.7×10^{-5}	Pr-143	0	1.1×10^{-6}	1.1×10^{-6}
Sr-89	3.2×10^{-3}	6.3×10^{-5}	3.3×10^{-3}	Pr-144	1.9×10^{-5}	0	1.9×10^{-5}
Sr-90	2.8×10^{-5}	1.5×10^{-5}	4.3×10^{-5}	W-187	1.9×10^{-4}	9.5×10^{-5}	2.8×10^{-4}
Sr-91	6.5×10^{-4}	5.9×10^{-4}	1.2×10^{-3}	Np-239	5.9×10^{-3}	1.6×10^{-3}	7.5×10^{-3}

[a] A wet site is characterized by the potential for effluent material to be emitted either through airborne or liquid pathways. A dry site only exhibits the potential to emit effluent material via the airborne pathway. For a dry site, it was conservatively assumed that liquid and atmospheric effluents are released into the atmosphere.

Source: HNUS 1996a.

Table M.2.3.1–5. Annual Liquid and Atmospheric Radioactive Releases From the Small Evolutionary Light Water Reactor Using a Mixed Oxide Core (curies)

	Release				Release		
	Wet Site[a]		Dry Site[a]		Wet Site[a]		Dry Site[a]
Isotope	Atmospheric	Liquid	Atmospheric	Isotope	Atmospheric	Liquid	Atmospheric
H-3	$8.4x10^1$	$7.5x10^2$	$8.4x10^2$	Nb-95	$2.1x10^{-3}$	$1.6x10^{-3}$	$3.7x10^{-3}$
C-14	7.3	0	7.3	Mo-99	0	$7.9x10^{-4}$	$7.9x10^{-4}$
Ar-41	$3.4x10^1$	0	$3.4x10^1$	Tc-99m	0	$4.6x10^{-4}$	$4.6x10^{-4}$
Kr-85m	$3.2x10^1$	0	$3.2x10^1$	Ru-103	$1.0x10^{-4}$	$1.8x10^{-3}$	$1.9x10^{-3}$
Kr-85	$1.7x10^2$	0	$1.7x10^2$	Rh-103m	0	$1.1x10^{-3}$	$1.1x10^{-3}$
Kr-87	9.5	0	9.5	Ru-106	$1.4x10^{-4}$	$3.9x10^{-2}$	$3.9x10^{-2}$
Kr-88	$3.4x10^1$	0	$3.4x10^1$	Ag-110m	0	$1.4x10^{-3}$	$1.4x10^{-3}$
Xe-131m	$2.0x10^3$	0	$2.0x10^3$	Sb-124	0	$4.3x10^{-4}$	$4.3x10^{-4}$
Xe-133m	$8.9x10^1$	0	$8.9x10^1$	Sb-125	$6.1x10^{-5}$	0	$6.1x10^{-5}$
Xe-133	$4.7x10^3$	0	$4.7x10^3$	Te-129m	0	$3.9x10^{-5}$	$3.9x10^{-5}$
Xe-135m	9.8	0	9.8	Te-129	0	$3.8x10^{-5}$	$3.8x10^{-5}$
Xe-135	$5.4x10^2$	0	$5.4x10^2$	Te-131m	0	$1.7x10^{-4}$	$1.7x10^{-4}$
Xe-138	4.6	0	4.6	Te-131	0	$3.0x10^{-5}$	$3.0x10^{-5}$
Na-24	0	$3.2x10^{-3}$	$3.2x10^{-3}$	I-131	$7.3x10^{-2}$	$3.6x10^{-2}$	$1.1x10^{-1}$
P-32	0	$1.8x10^{-4}$	$1.8x10^{-4}$	Te-132	0	$2.1x10^{-4}$	$2.1x10^{-4}$
Cr-51	$6.1x10^{-4}$	$5.2x10^{-3}$	$5.8x10^{-3}$	I-132	0	$2.4x10^{-3}$	$2.4x10^{-3}$
Mn-54	$4.4x10^{-4}$	$4.0x10^{-3}$	$4.4x10^{-3}$	I-133	$2.4x10^{-1}$	$2.0x10^{-2}$	$2.6x10^{-1}$
Fe-55	0	$7.4x10^{-3}$	$7.4x10^{-3}$	I-134	0	$8.6x10^{-5}$	$8.6x10^{-5}$
Co-57	$8.2x10^{-6}$	0	$8.2x10^{-6}$	Cs-134	$1.5x10^{-3}$	$1.8x10^{-2}$	$1.9x10^{-2}$
Co-58	$2.3x10^{-2}$	$8.6x10^{-3}$	$3.2x10^{-2}$	I-135	0	$1.4x10^{-2}$	$1.4x10^{-2}$
Co-60	$8.7x10^{-3}$	$1.4x10^{-2}$	$2.3x10^{-2}$	Cs-136	$1.1x10^{-4}$	$2.0x10^{-3}$	$2.1x10^{-3}$
Fe-59	$7.9x10^{-5}$	$2.2x10^{-3}$	$2.3x10^{-3}$	Cs-137	$3.7x10^{-3}$	$3.8x10^{-2}$	$4.2x10^{-2}$
Ni-63	0	$1.7x10^{-3}$	$1.7x10^{-3}$	Ba-140	$3.9x10^{-4}$	$2.5x10^{-3}$	$2.9x10^{-3}$
Zn-65	0	$8.0x10^{-5}$	$8.0x10^{-5}$	La-140	0	$2.6x10^{-3}$	$2.6x10^{-3}$
Sr-89	$1.7x10^{-3}$	$6.3x10^{-5}$	$1.8x10^{-3}$	Ce-141	$3.9x10^{-5}$	$2.4x10^{-4}$	$2.7x10^{-4}$
Sr-90	$6.0x10^{-4}$	$1.0x10^{-5}$	$6.1x10^{-4}$	Ce-143	0	$2.3x10^{-4}$	$2.3x10^{-4}$
Sr-91	0	$3.2x10^{-5}$	$3.2x10^{-5}$	Ce-144	0	$3.6x10^{-3}$	$3.6x10^{-3}$
Y-91m	0	$3.0x10^{-5}$	$3.0x10^{-5}$	Pr-144	0	$5.8x10^{-4}$	$5.8x10^{-4}$
Y-91	0	$5.7x10^{-5}$	$5.7x10^{-5}$	W-187	0	$2.2x10^{-4}$	$2.2x10^{-4}$
Y-93	0	$1.7x10^{-4}$	$1.7x10^{-4}$	Np-239	0	$1.0x10^{-4}$	$1.0x10^{-4}$
Zr-95	$8.5x10^{-4}$	$1.0x10^{-3}$	$1.9x10^{-3}$				

[a] A wet site is characterized by the potential for effluent material to be emitted either through airborne or liquid pathways. A dry site only exhibits the potential to emit effluent material via the airborne pathway. For a dry site, it was conservatively assumed that liquid and atmospheric effluents are released into the atmosphere.

Source: HNUS 1996a.

Table M.2.3.2–1. ***Potential Radiological Impacts From Normal Operation to Involved Workers of Disposition Technology Alternatives and Common Activities***

Facility	Years of Operation	Involved "Badged" Workforce	Average Worker Dose (mrem/yr)	Risk of Fatal Cancer[a]	Total Dose (person-rem/yr)	Fatal Cancers[a]
Front-End Processes (Common to Multiple Disposition Alternatives)						
Pit Disassembly and Conversion Facility [Text deleted.]	10	415	200	$1.3x10^{-3}$	83	0.33
Pu Conversion Facility [Text deleted.]	10	572	233	$9.3x10^{-4}$	133	0.53
MOX Fuel Fabrication Facility						
	17	125	250	$1.7x10^{-3}$	31	0.21
	23	125	250	$2.3x10^{-3}$	31	0.29
Plutonium Disposition Alternatives						
Direct Disposition Alternative						
Deep Borehole Complex	10	205	13	$5.2x10^{-5}$	2.7	0.011
Immobilized Disposition Alternative						
Ceramic Immobilization Facility	10	450	240	$9.8x10^{-4}$	110	0.44
Deep Borehole Complex	10	168	13	$5.2x10^{-5}$	2.2	$8.8x10^{-3}$
Vitrification Alternative	10	550	200	$8.0x10^{-4}$	110	0.44
Ceramic Immobilization Alternative	10	430	279	$1.1x10^{-3}$	120	0.48
Electrometallurgical Treatment Alternative	10	73	40	$1.6x10^{-4}$	2.9	0.012
Existing LWR	23	600 to 1,000	281 to 543	$2.6x10^{-3}$ to $5.0x10^{-3}$	172 to 602	1.6 to 5.5
Partially Completed LWR	23	1,050	360	$3.2x10^{-3}$	380	3.5
Evolutionary LWR						
Small	17	125	800	$5.4x10^{-3}$	100	0.68
Large	17	210	810	$5.5x10^{-3}$	170	1.2

[a] As the result of operations for the number of years given in the first column.

Source: LANL 1996b; LANL 1996c; LANL 1996d; LLNL 1996a; LLNL 1996b; LLNL 1996c; LLNL 1996d; LLNL 1996e; LLNL 1996g; LLNL 1996h; NRC 1995b; ORNL 1995b.

M.2.4 RADIOLOGICAL IMPACTS AT HANFORD SITE

This section presents the radiological impacts of the various storage and disposition alternatives at Hanford. Section M.2.4.1 presents the radiological releases and resulting impacts from facilities associated with No Action. Section M.2.4.2 presents the radiological releases and resulting impacts from the various alternatives.

For purposes of radiological impact modeling, Hanford was divided into seven separate areas which would release radioactivity in 2005. All potential release points in each area were aggregated into a single release point. Table M.2.4–1 presents the characteristics of each of the release points including location, release height, minimum distance, and annual average dispersion to the site boundary in each of 16 directions. In order to calculate the maximum site boundary dose (that is, the dose ultimately incurred to the site MEI), the dose from each release point to the "maximum receptor" (that is, potential MEI) associated with each of the other release points has been calculated. For further clarification on the definition of a "maximum receptor" refer to Section M.2.2.2. For example, the dose resulting from releases from the 100 Area, 200 West, 200 East, 300 Area, and the other storage and disposition alternatives (Washington Nuclear Power-1), has been determined for the maximum receptor from the 400 Area. Figure M.2.4–1 illustrates the location of each maximum receptor in relation to each release point. The maximum site boundary dose (that is, the dose ultimately incurred by the MEI) is then determined by the maximum dose to one of these maximum receptors. Table M.2.4–2 presents the distance, direction, and atmospheric dispersion from each release point to each of the maximum receptors. Annual radiological releases were assumed to remain constant during the full operational period.

Descriptions of population, food stuffs distributions, and aquatic foods for each release area are provided in a Health Risk Data report, October, 1996. The joint frequency distributions used for the dose assessment were based on measurements from the meteorological tower in the 200 East Area at the 10-m (33-ft) height during the time period of July 1, 1989 through August 30, 1990 and is contained in the Health Risk Data report.

Doses given in this section are associated with 1 year of operation because regulatory standards are given as annual limits. The health effects are presented on an annual basis in the tables, and for the projected operational period in the text. Tables M.2.4–3 through M.2.4–6 include the radiological impacts to the public from both atmospheric releases and from using the surface water for No Action and the storage and disposition alternatives.

M.2.4.1 No Action

Atmospheric Releases and Resulting Impacts to the Public. For No Action, five of the six areas have radioactive releases into the atmosphere from normal operation. Table M.2.4.1–1 presents the estimated annual atmospheric radioactive releases.

Tables M.2.4–3 and M.2.4–4 include the atmospheric radiological impacts to the maximally exposed member of the public and the offsite population within 80 km (50 mi), respectively. The MEI would receive an annual dose of 4.4×10^{-3} mrem. An estimated fatal cancer risk of 1.1×10^{-7} would result from 50 years of operation. The population within 80 km (50 mi) would receive a dose of 0.46 person-rem in 2030 (midlife of operation). An estimated 0.012 fatal cancers could result from 50 years of operation.

Liquid Releases and Resulting Impacts to the Public. For No Action, some areas may have radioactive releases to the offsite surface water from normal operation. Table M.2.4.1–2 presents the estimated annual liquid radioactive releases.

Tables M.2.4–5 and M.2.4–6, respectively, include the radiological impacts to the MEI and the offsite populations using surface water within 80 km (50 mi) downstream of Hanford. The maximally exposed member of the public would receive an annual dose of 9.5×10^{-4} mrem. An estimated fatal cancer risk of

Table M.2.4–1. Release Point Characteristics, Direction, Distance, and Chi/Q at the Hanford Site Boundary

Release Point[a]	100 Area	200 West	200 East	300 Area	400 Area	600 Area	WNP-1
Latitude	46°39'35.88"	46°33'22.33"	46°33'22.33"	46°22'14.09"	46°26'2.31"	46°23'37.94"	46°27'58.01"
Longitude	-119°36'32.33"	-119°37'43.30"	-119°32'44.96"	-119°16'40.9"	-119°21'27.50"	-119°32'0.52"	-119°18'44.30"
Release Height	12.8 m	61.0 m	61.0 m	17.9 m	14.3 m	Ground Level	Ground Level

Distance and Atmospheric Dispersion at Site Boundary														
Direction	Distance (m)	Chi/Q (s/m^3)	Distance (m)	Chi/Q (s/m^3)	Distance (m)	Chi/Q (s/m^3)	Distance (m)	Chi/Q (s/m^3)	Distance (m)	Chi/Q (s/m^3)	Distance (m)	Chi/Q (s/m^3)	Distance (m)	Chi/Q (s/m^3)
N	8,727	$4.0x10^{-8}$	17,234	$4.6x10^{-9}$	22,325	$3.4x10^{-9}$	9,361	$2.8x10^{-8}$	16,086	$1.5x10^{-8}$	38,245	$5.7x10^{-9}$	10,853	$3.1x10^{-8}$
NNE	12,004	$2.1x10^{-8}$	24,489	$2.2x10^{-9}$	25,670	$2.1x10^{-9}$	2,388	$1.3x10^{-7}$	12,934	$1.6x10^{-8}$	30,461	$6.4x10^{-9}$	7,855	$4.0x10^{-8}$
NE	17,712	$2.2x10^{-8}$	26,784	$3.6x10^{-9}$	20,224	$4.9x10^{-9}$	1,587	$3.7x10^{-7}$	9,821	$4.2x10^{-8}$	25,390	$1.4x10^{-8}$	5,295	$1.2x10^{-7}$
ENE	20,510	$2.8x10^{-8}$	24,022	$6.2x10^{-9}$	17,492	$8.7x10^{-9}$	1,413	$6.5x10^{-7}$	7,922	$8.6x10^{-8}$	22,039	$2.7x10^{-8}$	4,865	$2.2x10^{-7}$
E	20,590	$4.6x10^{-8}$	23,513	$9.1x10^{-9}$	17,205	$1.3x10^{-8}$	1,407	$9.4x10^{-7}$	7,817	$1.4x10^{-7}$	7,861	$1.8x10^{-7}$	4,216	$4.5x10^{-7}$
ESE	22,165	$4.3x10^{-8}$	28,561	$8.5x10^{-9}$	22,180	$1.1x10^{-8}$	1,492	$9.8x10^{-7}$	7,846	$1.5x10^{-7}$	5,867	$2.8x10^{-7}$	4,212	$4.5x10^{-7}$
SE	31,482	$2.2x10^{-8}$	24,266	$9.1x10^{-9}$	26,251	$8.4x10^{-9}$	1,883	$6.9x10^{-7}$	8,746	$1.1x10^{-7}$	2,748	$7.2x10^{-7}$	5,313	$2.7x10^{-7}$
SSE	32,668	$8.5x10^{-9}$	20,740	$5.7x10^{-9}$	21,058	$5.6x10^{-9}$	2,147	$2.8x10^{-7}$	9,120	$4.2x10^{-8}$	2,266	$4.1x10^{-7}$	7,248	$7.0x10^{-8}$
S	26,544	$1.6x10^{-8}$	14,929	$9.8x10^{-9}$	19,177	$7.4x10^{-9}$	2,137	$3.5x10^{-7}$	7,915	$6.9x10^{-8}$	2,225	$5.7x10^{-7}$	12,429	$4.5x10^{-8}$
SSW	25,867	$8.7x10^{-9}$	15,132	$5.3x10^{-9}$	16,507	$4.8x10^{-9}$	2,241	$1.8x10^{-7}$	7,482	$4.1x10^{-8}$	2,841	$2.1x10^{-7}$	12,298	$2.5x10^{-8}$
SW	17,092	$7.2x10^{-9}$	14,979	$3.7x10^{-9}$	17,560	$3.0x10^{-9}$	2,560	$8.5x10^{-8}$	7,422	$2.0x10^{-8}$	2,626	$1.2x10^{-7}$	12,393	$1.2x10^{-8}$
WSW	15,068	$7.9x10^{-9}$	12,638	$4.0x10^{-9}$	19,118	$2.4x10^{-9}$	3,677	$4.6x10^{-8}$	12,536	$9.0x10^{-9}$	3,709	$6.4x10^{-8}$	17,723	$6.5x10^{-9}$
W	10,665	$2.7x10^{-8}$	12,346	$8.9x10^{-9}$	18,701	$5.3x10^{-9}$	5,874	$5.1x10^{-8}$	19,209	$1.1x10^{-8}$	4,804	$1.2x10^{-7}$	25,540	$8.5x10^{-9}$
WNW	8,593	$3.2x10^{-8}$	12,546	$6.9x10^{-9}$	18,995	$4.1x10^{-9}$	27,312	$5.3x10^{-9}$	33,445	$4.5x10^{-9}$	6,527	$5.0x10^{-8}$	37,072	$4.5x10^{-9}$
NW	7,289	$7.9x10^{-8}$	14,910	$9.9x10^{-9}$	19,803	$7.1x10^{-9}$	46,357	$5.2x10^{-9}$	38,932	$7.2x10^{-9}$	23,021	$1.7x10^{-8}$	38,585	$8.3x10^{-9}$
NNW	7,399	$7.3x10^{-8}$	15,721	$8.0x10^{-9}$	19,540	$6.2x10^{-9}$	47,598	$4.7x10^{-9}$	39,255	$6.7x10^{-9}$	33,663	$9.5x10^{-9}$	36,707	$8.5x10^{-9}$

[a] See Figure M.2.4–1 for location of release points.

Note: Release from the 600 Area are conservatively assumed to be near Rattlesnake Mountain.

Source: HNUS 1996a.

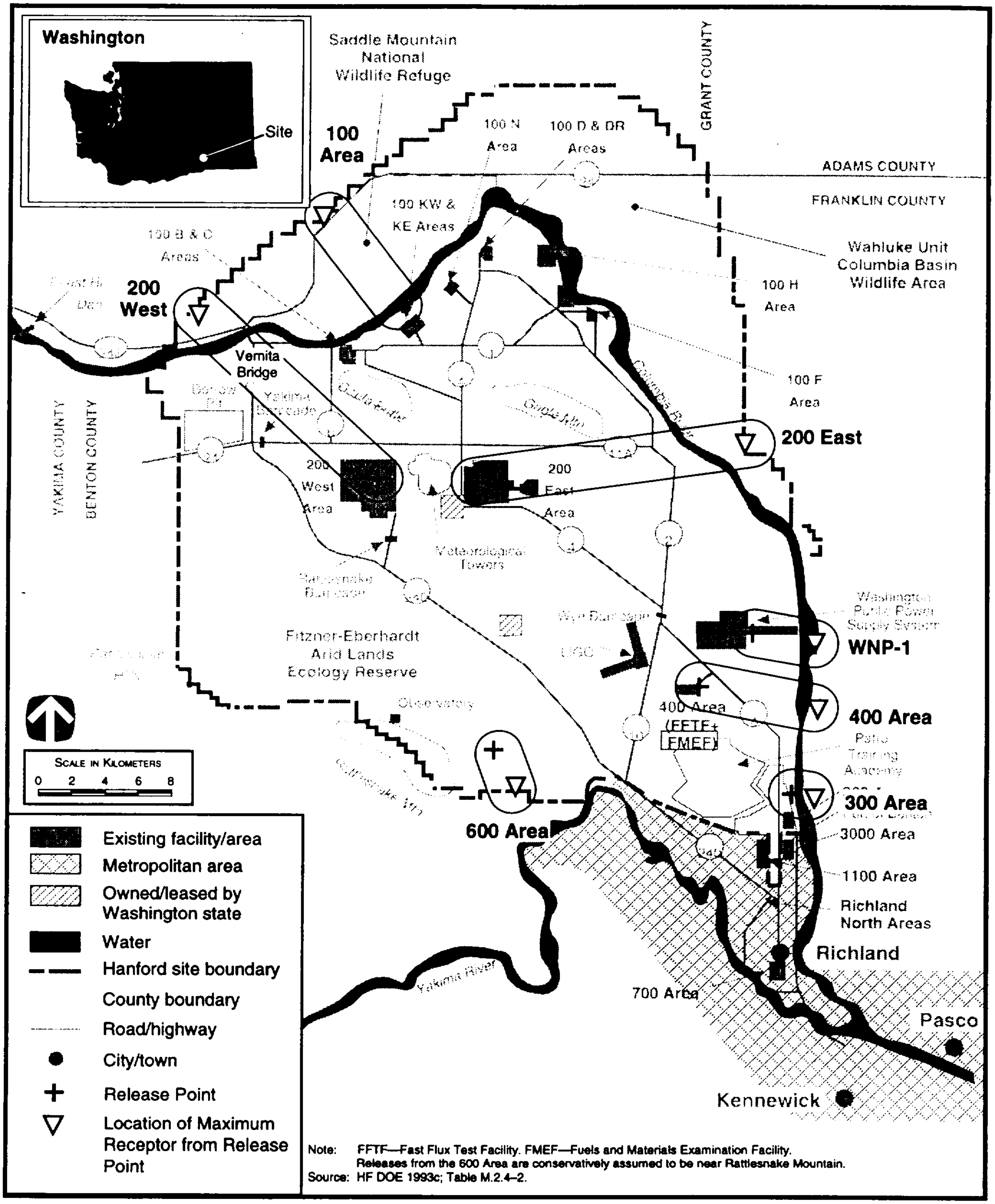


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Figure M.2.4–1. Location of Release Points and Maximum Receptors at Hanford Site.

Table M.2.4–2. Direction, Distance, and Meteorological Dispersion to Various Maximum Individual Receptors at the Hanford Site Boundary

Maximum Receptor For	Direction	Distance (m)	Atmospheric Dispersion Chi/Q (s/m^3)
Release Point: 100 Area			
100 Area	NW	7,289	$7.9x10^{-8}$
200 West	W	12,214	$2.3x10^{-8}$
200 East	ESE	23,726	$3.9x10^{-8}$
300 Area	SE	42,124	$1.5x10^{-8}$
400 Area	SE	37,783	$1.8x10^{-8}$
600 Area	S	32,656	$1.2x10^{-8}$
WNP-1	SE	34,885	$1.9x10^{-8}$
Release Point: 200 West			
100 Area	N	17,235	$4.6x10^{-9}$
200 West	NW	14,910	$9.9x10^{-9}$
200 East	E	23,514	$9.1x10^{-9}$
300 Area	SE	35,271	$6.0x10^{-9}$
400 Area	ESE	32,194	$7.5x10^{-9}$
600 Area	SSE	22,149	$5.3x10^{-9}$
WNP-1	ESE	30,381	$7.9x10^{-9}$
Release Point: 200 East			
100 Area	NNW	19,541	$6.2x10^{-9}$
200 West	WNW	19,965	$3.9x10^{-9}$
200 East	E	17,205	$1.3x10^{-8}$
300 Area	SE	30,363	$7.1x10^{-9}$
400 Area	SE	26,701	$8.2x10^{-9}$
600 Area	S	20,407	$6.9x10^{-9}$
WNP-1	ESE	34,885	$6.9x10^{-9}$
Release Point: 300 Area			
100 Area	NW	48,259	$4.9x10^{-9}$
200 West	NW	48,764	$4.9x10^{-9}$
200 East	N	23,223	$8.4x10^{-9}$
300 Area	ESE	1,493	$9.8x10^{-7}$
400 Area	NNE	5,963	$4.0x10^{-8}$
600 Area	W	18,045	$1.1x10^{-8}$
WNP-1	N	10,083	$2.5x10^{-8}$

Table M.2.4–2. Direction, Distance, and Meteorological Dispersion to Various Maximum Individual Receptors at the Hanford Site Boundary—Continued

Maximum Receptor For	Direction	Distance (m)	Atmospheric Dispersion Chi/Q (s/m^3)
Release Point: 400 Area			
100 Area	NW	38,933	$7.2x10^{-9}$
200 West	NW	39,581	$7.0x10^{-9}$
200 East	N	16,127	$1.5x10^{-8}$
300 Area	SE	10,547	$8.3x10^{-8}$
400 Area	ESE	7,846	$1.5x10^{-7}$
600 Area	WSW	13,655	$8.0x10^{-9}$
WNP-1	ENE	8,188	$8.2x10^{-8}$
Release Point: 600 Area			
100 Area	NNW	36,551	$8.6x10^{-9}$
200 West	NNW	33,674	$9.5x10^{-9}$
200 East	NE	25,978	$1.4x10^{-8}$
300 Area	E	21,313	$4.6x10^{-8}$
400 Area	E	21,493	$4.6x10^{-8}$
600 Area	SE	2,748	$7.2x10^{-7}$
WNP-1	ENE	22,418	$2.6x10^{-8}$
Release Point: WNP-1			
100 Area	NW	38,611	$8.3x10^{-9}$
200 West	WNW	40,473	$4.0x10^{-9}$
200 East	N	12,370	$2.6x10^{-8}$
300 Area	SSE	11,643	$3.5x10^{-8}$
400 Area	SE	6,472	$2.0x10^{-7}$
600 Area	WSW	18,493	$6.2x10^{-9}$
WNP-1	E	4,216	$4.5x10^{-7}$

Source: HNUS 1996a.

$2.4x10^{-8}$ would result from 50 years of operation. The population would receive a dose of 1.1 person-rem in 2030. An estimated 0.028 fatal cancers could result from 50 years of operation.

Worker Doses and Health Effects. Based on measured values during 1991 and 1992, it is estimated that the average dose to a badged worker involved in No Action activities at Hanford in 2005 and beyond would equal 27 mrem. It is projected that in 2005 and beyond, there would be 9,300 badged workers involved in No Action activities. The annual dose among all these workers would equal 250 person-rem. From 50 years of operation, an estimated fatal cancer risk of $5.5x10^{-4}$ would result to the average worker and 5.1 fatal cancers could result among all workers.

Table M.2.4–3. Doses and Resulting Health Effects to the Maximally Exposed Individual at Hanford Site From Atmospheric Releases Associated With Annual Normal Operation

Alternative/Facility	Dose by Pathway (mrem) Inhalation	Ingestion	Plume Immersion	Ground Shine	Committed Effective Dose Equivalent (mrem)	Percent of Background[a]	Estimated 1-Year Fatal Cancer Risk
No Action (Total Site)	$9.9x10^{-4}$	$2.9x10^{-3}$	$4.2x10^{-4}$	$1.4x10^{-6}$	$4.4x10^{-3}$[b]	$1.5x10^{-3}$	$2.2x10^{-9}$
Upgraded Storage Facility-200 West[c]	$3.9x10^{-7}$	$8.5x10^{-9}$	$2.3x10^{-15}$	$3.4x10^{-12}$	$4.0x10^{-7}$	$1.3x10^{-7}$	$2.0x10^{-13}$
Upgraded Storage Facility-Fuels and Materials Examination Facility[c]	$1.7x10^{-6}$	$3.8x10^{-8}$	$1.0x10^{-14}$	$1.6x10^{-11}$	$1.8x10^{-6}$	$6.0x10^{-7}$	$9.0x10^{-13}$
Consolidated Storage Facility	$2.5x10^{-6}$	$4.4x10^{-9}$	$9.6x10^{-16}$	$2.0x10^{-12}$	$2.5x10^{-6}$	$8.3x10^{-7}$	$1.2x10^{-12}$
Collocated Storage Facility	$2.5x10^{-6}$	$4.4x10^{-9}$	$1.0x10^{-15}$	$3.0x10^{-12}$	$2.5x10^{-6}$	$8.3x10^{-7}$	$1.2x10^{-12}$
Pit Disassembly/Conversion Facility	$2.8x10^{-4}$	$6.3x10^{-6}$	$1.6x10^{-12}$	$2.5x10^{-9}$	$2.9x10^{-4}$	$9.7x10^{-5}$	$1.4x10^{-10}$
Pu Conversion Facility	$1.8x10^{-4}$	$3.4x10^{-7}$	$7.7x10^{-14}$	$1.6x10^{-10}$	$1.8x10^{-4}$	$6.0x10^{-5}$	$9.0x10^{-11}$
MOX Fuel Fabrication Facility	$1.4x10^{-4}$	$2.4x10^{-7}$	$5.2x10^{-14}$	$2.5x10^{-10}$	$1.4x10^{-4}$	$4.7x10^{-5}$	$7.0x10^{-11}$
Ceramic Immobilization Facility (Immobilized Disposition)	$3.2x10^{-8}$	$5.6x10^{-11}$	$1.2x10^{-17}$	$2.5x10^{-14}$	$3.2x10^{-8}$	$1.1x10^{-8}$	$1.6x10^{-14}$
Deep Borehole Complex (Direct Disposition)	$5.3x10^{-9}$	$7.6x10^{-11}$	$2.0x10^{-17}$	$3.1x10^{-14}$	$5.3x10^{-9}$	$1.8x10^{-9}$	$2.7x10^{-15}$
Deep Borehole Complex (Immobilized Disposition)	$6.6x10^{-9}$	$1.1x10^{-10}$	$3.0x10^{-17}$	$4.5x10^{-14}$	$6.7x10^{-9}$	$2.2x10^{-9}$	$3.4x10^{-15}$
Vitrification Facility	$1.3x10^{-5}$	$8.6x10^{-7}$	$2.5x10^{-10}$	$1.3x10^{-7}$	$1.4x10^{-5}$	$4.7x10^{-6}$	$7.0x10^{-12}$
Ceramic Immobilization Facility (Ceramic Immobilization)	$3.6x10^{-8}$	$1.7x10^{-7}$	$5.1x10^{-11}$	$2.8x10^{-8}$	$2.3x10^{-7}$	$7.7x10^{-8}$	$1.2x10^{-13}$
Advanced Boiling Water Reactor	$5.4x10^{-3}$	$3.2x10^{-1}$	$1.2x10^{-1}$	$7.1x10^{-3}$	$4.5x10^{-1}$	$1.5x10^{-1}$	$2.3x10^{-7}$
CE System 80+ Reactor	$1.1x10^{-2}$	$3.1x10^{-1}$	$8.7x10^{-3}$	$1.5x10^{-4}$	$3.3x10^{-1}$	$1.1x10^{-1}$	$1.7x10^{-7}$
[Text deleted.]							
AP600 Reactor	$2.5x10^{-3}$	$2.1x10^{-1}$	$2.5x10^{-2}$	$1.5x10^{-3}$	$2.3x10^{-1}$	$7.7x10^{-2}$	$1.2x10^{-7}$
RESAR 90 Reactor	$8.9x10^{-3}$	$3.2x10^{-1}$	$1.0x10^{-2}$	$1.7x10^{-3}$	$3.4x10^{-1}$	$1.1x10^{-1}$	$1.7x10^{-7}$

[a] Individual annual natural background radiation dose is equal to 300 mrem.

[b] The storage facility contributes $4.1x10^{-4}$ mrem/year.

[c] The radiological impacts for the Upgrade Alternative are calculated based on measured releases from facilities at Hanford, RFETS, and LANL.

[Text deleted.]

Source: HNUS 1996a.

Table M.2.4–4. Doses and Resulting Health Effects to the Population Within 80 Kilometers of Hanford Site From Atmospheric Releases Associated With Normal Operation in 2030

	Dose by Pathway (person-rem)						
Alternative/Facility	**Inhalation**	**Ingestion**	**Plume Immersion**	**Ground Shine**	**Committed Effective Dose Equivalent (person-rem)**	**Percent of Background[a]**	**Estimated 1-Year Fatal Cancer Risk**
No Action (Total Site)	$5.2x10^{-2}$	$4.1x10^{-1}$	$4.7x10^{-3}$	$1.5x10^{-4}$	$4.6x10^{-1}$[b]	$2.3x10^{-4}$	$2.3x10^{-4}$
Upgraded Storage Facility-200 West[c]	$2.8x10^{-5}$	$7.6x10^{-6}$	$1.6x10^{-13}$	$2.4x10^{-10}$	$3.5x10^{-5}$	$1.9x10^{-8}$	$1.8x10^{-8}$
Upgraded Storage Facility-Fuels Materials Examination Facility[c]	$3.6x10^{-5}$	$1.1x10^{-5}$	$2.1x10^{-13}$	$3.2x10^{-10}$	$4.7x10^{-5}$	$2.5x10^{-8}$	$2.4x10^{-8}$
Consolidated Storage Facility	$1.1x10^{-4}$	$2.9x10^{-6}$	$4.2x10^{-14}$	$8.8x10^{-11}$	$1.1x10^{-4}$	$5.9x10^{-8}$	$5.5x10^{-8}$
Collocated Storage Facilities	$1.1x10^{-4}$	$2.9x10^{-6}$	$4.5x10^{-14}$	$1.3x10^{-10}$	$1.1x10^{-4}$	$5.9x10^{-8}$	$5.5x10^{-8}$
Pit Disassembly/Conversion Facility	$1.2x10^{-2}$	$4.1x10^{-3}$	$7.2x10^{-11}$	$1.1x10^{-7}$	$1.6x10^{-2}$	$8.6x10^{-6}$	$8.0x10^{-6}$
Pu Conversion Facility	$8.2x10^{-3}$	$2.3x10^{-4}$	$3.4x10^{-12}$	$7.2x10^{-9}$	$8.4x10^{-3}$	$4.5x10^{-6}$	$4.2x10^{-6}$
MOX Fuel Fabrication Facility	$6.0x10^{-3}$	$1.6x10^{-4}$	$2.3x10^{-12}$	$1.1x10^{-8}$	$6.2x10^{-3}$	$3.3x10^{-6}$	$3.1x10^{-6}$
Ceramic Immobilization Facility (Immobilized Disposition)	$1.4x10^{-6}$	$3.6x10^{-8}$	$5.6x10^{-16}$	$1.1x10^{-12}$	$1.5x10^{-6}$	$8.0x10^{-10}$	$7.5x10^{-10}$
Deep Borehole Complex (Direct Disposition)	$2.3x10^{-7}$	$5.0x10^{-8}$	$8.8x10^{-16}$	$1.3x10^{-12}$	$2.8x10^{-7}$	$1.5x10^{-10}$	$1.4x10^{-10}$
Deep Borehole Complex (Immobilized Disposition)	$2.9x10^{-7}$	$7.4x10^{-8}$	$1.3x10^{-15}$	$2.0x10^{-12}$	$3.7x10^{-7}$	$2.0x10^{-10}$	$1.9x10^{-10}$
Vitrification Facility	$5.8x10^{-4}$	$2.0x10^{-4}$	$1.1x10^{-8}$	$6.1x10^{-6}$	$7.9x10^{-4}$	$4.2x10^{-7}$	$4.0x10^{-7}$
Ceramic Immobilization Facility (Ceramic Immobilization)	$1.6x10^{-6}$	$3.6x10^{-5}$	$2.2x10^{-9}$	$1.2x10^{-6}$	$3.9x10^{-5}$	$2.1x10^{-8}$	$1.9x10^{-8}$
Advanced Boiling Water Reactor	$2.9x10^{-2}$	$2.6x10^{1}$	$3.0x10^{-1}$	$3.5x10^{-2}$	$2.6x10^{1}$	$1.4x10^{-2}$	$1.3x10^{-2}$
CE System 80+ Reactor	$7.2x10^{-2}$	$3.0x10^{1}$	$4.0x10^{-2}$	$9.3x10^{-4}$	$3.0x10^{1}$	$1.6x10^{-2}$	$1.5x10^{-2}$
[Text deleted.]							
AP600 Reactor	$1.6x10^{-2}$	$2.0x10^{1}$	$1.3x10^{-1}$	$9.6x10^{-3}$	$2.0x10^{1}$	$1.1x10^{-2}$	$1.0x10^{-2}$
RESAR 90 Reactor	$5.8x10^{-2}$	$2.9x10^{1}$	$5.4x10^{-2}$	$1.1x10^{-2}$	$2.9x10^{1}$	$1.6x10^{-2}$	$1.5x10^{-2}$

[a] Dose to the population within 80 km from natural background radiation in the year 2030 is equal to 186,400 person-rem.

[b] The storage facility contributes 0.047 person-rem/year.

[c] The radiological impacts for the Upgrade Alternative are calculated based on measured releases from facilities at Hanford, RFETS, and LANL.

[Text deleted.]

Source: HNUS 1996a.

Table M.2.4–5. Doses and Resulting Health Effects to the Maximally Exposed Individual at Hanford Site From Liquid Releases Associated With Annual Normal Operation

	Dose by Pathway (mrem)								
Alternative/Facility	Fish Ingestion	Other Food Ingestion	Drinking Water	Boating	Swimming	Shoreline	Committed Effective Dose Equivalent (mrem)	Percent of Background[a]	Estimated 1-Year Fatal Cancer Risk
No Action (Total Site)	5.2×10^{-4}	4.2×10^{-4}	0	1.1×10^{-8}	2.1×10^{-8}	3.2×10^{-6}	9.5×10^{-4}[b]	3.2×10^{-4}	4.8×10^{-10}
Advanced Boiling Water Reactor	4.6×10^{-3}	9.5×10^{-5}	0	1.1×10^{-7}	2.2×10^{-7}	1.2×10^{-5}	4.7×10^{-3}	1.6×10^{-3}	2.3×10^{-9}
CE System 80+ Reactor	1.4×10^{-2}	4.8×10^{-4}	0	2.1×10^{-7}	4.3×10^{-7}	3.3×10^{-5}	1.4×10^{-2}	4.8×10^{-3}	7.2×10^{-9}
AP600 Reactor	2.2×10^{-2}	7.9×10^{-4}	0	2.4×10^{-7}	4.8×10^{-7}	3.5×10^{-5}	2.4×10^{-2}	7.9×10^{-3}	1.2×10^{-8}
[Text deleted.]									
RESAR-90 Reactor	1.5×10^{-2}	8.9×10^{-4}	0	2.4×10^{-7}	4.7×10^{-7}	2.0×10^{-5}	1.6×10^{-2}	5.3×10^{-3}	7.9×10^{-9}

[a] Individual annual natural background radiation dose is equal to 300 mrem.
[b] The storage facility does not contribute to the dose.
Source: HNUS 1996a.

Table M.2.4–6. Doses and Resulting Health Effects to the Population Within 80 Kilometers of Hanford Site From Liquid Releases Associated With Normal Operation in 2030

	Dose by Pathway (person-rem)								
Alternative/Facility	Fish Ingestion	Other Food Ingestion	Drinking Water	Boating	Swimming	Shoreline	Committed Effective Dose Equivalent (person-rem)	Percent of Background[a]	Estimated 1-Year Fatal Cancers
No Action (Total Site)	1.9×10^{-4}	1.1	1.0×10^{-3}	6.8×10^{-8}	2.7×10^{-7}	1.4×10^{-5}	1.1[b]	7.3×10^{-4}	5.5×10^{-4}
Advanced Boiling Water Reactor	1.7×10^{-3}	3.3×10^{-1}	1.7×10^{-3}	6.9×10^{-7}	2.7×10^{-6}	5.2×10^{-5}	3.3×10^{-1}	2.2×10^{-4}	1.7×10^{-4}
CE System 80+ Reactor	5.1×10^{-3}	1.5	1.1×10^{-2}	1.3×10^{-6}	5.3×10^{-6}	1.4×10^{-4}	1.5	1.0×10^{-3}	7.6×10^{-4}
AP600 Reactor	8.7×10^{-3}	2.6	1.9×10^{-2}	1.5×10^{-6}	6.0×10^{-6}	1.5×10^{-4}	2.6	1.7×10^{-3}	1.3×10^{-3}
[Text deleted.]									
RESAR-90 Reactor	5.5×10^{-3}	2.7	2.4×10^{-2}	1.5×10^{-6}	6.0×10^{-6}	8.5×10^{-5}	2.7	1.8×10^{-3}	1.4×10^{-3}

[a] Dose to the population within 80 km from natural background radiation in the year 2030 is equal to 186,400 person-rem.
[b] The storage facility does not contribute to the dose.
Source: HNUS 1996a.

Table M.2.4.1–1. Annual Atmospheric Radioactive Releases From Normal Operation of No Action at Hanford Site (curies)

Isotope	100 Area	200 East	200 West[a]	300 Area	400 Area	600 Area	No Action Storage
H-3	0	0	0	11.6	2.10	0	0
[Text deleted.]							
Co-60	5.22x10^{-6}	0	0	1.40x10^{-8}	0	0	0
Sr-90	5.43x10^{-5}	1.44x10^{-4}	8.4x10^{-5}	4.15x10^{-5}	0	1.80x10^{-7}	4.4x10^{-5}
Ru-106	1.31x10^{-5}	0	0	0	0	0	0
Sb-125	6.01x10^{-6}	0	0	1.51x10^{-6}	0	0	0
I-129	0	4.85x10^{-3}	4.0x10^{-6}	0	0	0	0
Cs-134	8.89x10^{-8}	0	0	3.30x10^{-7}	0	0	0
Cs-137	1.61x10^{-4}	1.50x10^{-3}	2.3x10^{-4}	9.34x10^{-7}	8.22x10^{-6}	0	0
Pm-147	0	1.10x10^{-4}	0	0	0	0	0
Eu-154	6.28x10^{-6}	0	0	1.49x10^{-6}	0	0	0
Eu-155	2.84x10^{-6}	0	0	2.60x10^{-8}	0	0	0
Pb-212	0	9.70x10^{-4}	0	0	0	0	0
Rn-222	0	0	0	1.50	0	0	0
[Text deleted.]							
Pu-238	1.03x10^{-6}	3.20x10^{-6}	0	6.85x10^{-8}	0	0	0
Pu-239	8.21x10^{-6}	1.12x10^{-5}	3.8x10^{-5}	8.44x10^{-6}	2.38x10^{-6}	4.00x10^{-8}	5.1x10^{-4}
Pu-241	0	3.30x10^{-5}	0	0	0	0	3.4x10^{-3}
Am-241	5.41x10^{-6}	2.78x10^{-5}	5.5x10^{-6}	5.51x10^{-8}	0	0	9.4x10^{-5}

[a] Presented releases do not include those associated with storage operations.
Source: HF PNL 1994b.

Table M.2.4.1–2. Annual Liquid Releases From Normal Operation of No Action at Hanford Site (curies)

Isotope	Release[a]
H-3	0.38
Co-60	3.6x10^{-4}
Sr-90	0.11
Ru-106	1.6x10^{-3}
Sb-125	1.3x10^{-4}
Cs-134	4.7x10^{-5}
Cs-137	4.4x10^{-4}
Pu-239	1.4x10^{-7}

[a] Total site release.
Source: HF PNL 1994b.

M.2.4.2 Storage and Disposition

Atmospheric Releases and Resulting Impacts to the Public. Total site radiological impacts during operation of storage or disposition facilities can be found by adding the impacts resulting from No Action facilities to the changes in impacts resulting from storage or disposition facilities. For example, to determine the radiological impact for the addition of the AP600 reactor at Hanford, the No Action facilities doses would be summed with the AP600 reactor doses. Estimated annual atmospheric radioactive releases for the storage and disposition facilities are given in Section M.2.3. Tables M.2.4–3 and M.2.4–4 include the atmospheric radiological impacts by alternative facility.

The annual doses associated with the different alternative facilities range from 5.3×10^{-9} to 0.45 mrem to the maximally exposed member of the public and from 2.8×10^{-7} to 30 person-rem to the 80-km (50-mi) population in 2030. The associated health effects from annual operations are included in both tables.

Liquid Releases and Resulting Impacts to the Public. There are two disposition technologies that would release liquid discharges to the surface water surrounding Hanford. These are the large and small evolutionary LWRs. The liquid releases for these technologies are given in Section M.2.3. As an example of determining the total site liquid radiological impact associated with the addition of an AP600 reactor at Hanford, the No Action liquid doses must be summed with the AP600 reactor liquid doses. Tables M.2.4–5 and M.2.4–6 present the liquid radiological impacts for the applicable alternative facilities.

The annual doses associated with the different LWR's that have liquid releases range from 4.7×10^{-3} to 0.024 mrem to the maximally exposed member of the public, and range from 0.33 to 2.7 person-rem to the downstream population in 2030. The associated health effects from annual operations are included in both tables.

Worker Doses and Health Effects. For the storage and disposition alternatives, the impacts from the No Action facilities need to be added to the changes in impacts from the storage or disposition facilities to determine the impacts from total site operation (refer to the worker discussion under No Action, above, and to Table M.2.3.2–1).