APPENDIX H:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR THE MANUFACTURE AND USE OF URANIUM OXIDE AND URANIUM METAL

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NOTATION (APPENDIX H)

The following is a list of acronyms and abbreviations, including units of measure, used in this document. Some acronyms used only in tables are defined in those tables.

ACRONYMS AND ABBREVIATIONS

General

CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
HEPA	high-efficiency particulate air (filter)
HLW	high-level radioactive waste
LCF	latent cancer fatality
LLNL	Lawrence Livermore National Laboratory
LLW	low-level radioactive waste
MEI	maximally exposed individual
NEPA	*National Environmental Policy Act*
NRC	U.S. Nuclear Regulatory Commission
PEIS	programmatic environmental impact statement
PM_{10}	particulate matter with a mean diameter of 10 µm or less

Chemicals

CO	carbon monoxide
HC	hydrocarbons
NO_x	nitrogen oxides
UF_6	uranium hexafluoride
UO_2	uranium dioxide
U_3O_8	triuranium octaoxide (uranyl uranate)

UNITS OF MEASURE

ft	foot (feet)	lb	pound(s)
g	gram(s)	µg	microgram(s)
gal	gallon(s)	µm	micrometer(s)
gpm	gallon(s) per minute	m	meter(s)
ha	hectare(s)	m^3	cubic meter(s)
km	kilometer(s)	mi^2	square mile(s)
km^2	square kilometer(s)	min	minute(s)

mrem	millirem(s)
MW	megawatt(s)
MWyr	megawatt year(s)
rem	roentgen equivalent man
s	second(s)
scf	standard cubic foot (feet)
ton(s)	short ton(s)
yd^3	cubic yard(s)
yr	year(s)

APPENDIX H:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR THE MANUFACTURE AND USE OF URANIUM OXIDE AND URANIUM METAL

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites in Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period 1999 through 2039. This appendix provides detailed information describing the manufacture and use options considered in the PEIS. The discussion provides background information for the manufacture and use of oxide and metal, as well as a summary of the estimated environmental impacts associated with each option.

Manufacture and Use Options

The representative manufacture and use options analyzed in detail in the PEIS consider using depleted uranium as radiation shielding material. Even though uranium is radioactive itself, it can be used effectively to shield gamma radiation from highly radioactive material — such as spent nuclear fuel — because it is very dense. Two representative options are considered:

Uranium Oxide Shielding Option. This option considers the manufacture and use of uranium oxide storage casks for spent nuclear fuel using a uranium concrete material similar to conventional concrete but containing high-density uranium oxide (UO_2) in place of normal aggregate (typically gravel).

Uranium Metal Shielding Option. This option considers the manufacture and use of uranium metal casks for the storage, transport, and disposal of spent nuclear fuel (sometimes called a multi-purpose unit).

Several current and potential uses exist for depleted uranium. Depleted uranium could be mixed with highly enriched uranium from retired nuclear weapons to produce nuclear reactor fuel. This process is called blending, and, to date, only natural uranium has been considered for this application. Depleted uranium is currently used as a counterweight in high-performance aircraft. Such uses can be expected in the future, and there are other potential uses as counterweights on forklifts and as flywheels. Military applications of depleted uranium include use as tank armor, armor piercing projectiles (antitank weapons), and counterweights in missiles.

The two use alternatives evaluated in detail in the PEIS, use as uranium oxide and use as uranium metal as radiation shielding, were selected as representative options for the purposes of comparing the potential environmental impacts of broad alternative management strategies. These options were selected in part because a recent market study suggests that the largest potential market for depleted uranium currently appears to be in shielding applications (Kaplan 1995). However, the selection of these use options for analysis in the PEIS was not intended to imply that the PEIS will be used to select a specific end use or preclude other potential uses in the future. If a use strategy is selected in the Record of Decision, specific uses would be considered and evaluated in more detail in future planning and environmental analyses, as appropriate.

Shielding is any material that is placed between a source of radiation and people, equipment, or other objects, in order to absorb the radiation and thereby reduce radiation exposure. Common shielding materials include concrete, steel, water, and lead. For shielding gamma radiation sources, the more dense a material is, the more effective it is as a shield. Therefore, even though uranium is radioactive itself, it can be used effectively to shield more highly penetrating radiation because of its density. Uranium is one of the most dense materials known, being 1.6 times more dense than lead.

The PEIS evaluates two options for the manufacture and use of depleted uranium shielding: (1) the uranium oxide option, which is based on the use of dense uranium dioxide (UO_2); and (2) the uranium metal option, based on the use of uranium metal. Both options assume that the depleted uranium would be used as the primary shielding material in containers (called "casks") used to store spent nuclear fuel. Spent nuclear fuel is the highly radioactive "used" fuel produced in nuclear power plants. Although spent nuclear fuel is most commonly shielded by water in large storage pools, there is a growing need for heavily shielded storage casks. A typical storage cask is a cylindrical container about 15 ft (4.5 m) high and 5 ft (1.5 m) in diameter (see Figure H.1). For both options, the cask designs are based on existing designs, and assume that the uranium shielding material would be enclosed between stainless steel (or equivalent) shells (Lawrence Livermore National Laboratory [LLNL] 1997).

The uranium oxide option assumes that depleted uranium in the form of high density UO_2 would be used for the manufacture of depleted uranium concrete for shielding in spent nuclear fuel storage casks. This uranium concrete material, which substitutes dense UO_2 for the coarse aggregate (typically gravel) in conventional concrete, is known as DUCRETE. As a shielding material, DUCRETE offers size and weight advantages compared to conventional concrete. Shielding made of DUCRETE would typically require less than half the thickness of shielding made from concrete to obtain the same effect.

The uranium metal option assumes that depleted uranium in the form of metal would be used for the manufacture of shielding in a spent nuclear fuel cask that could be used not only for storage, but also for transportation and disposal. This type of cask is commonly called a multi-purpose unit. No assumptions were made regarding the fate of the uranium oxide or uranium metal casks after use. The empty casks could be recycled, stored, or disposed of as low-level radioactive waste (LLW).

For assessment purposes, the manufacture of depleted uranium shielded casks was assumed to take place at a stand-alone industrial plant dedicated to the cask fabrication process. In general,

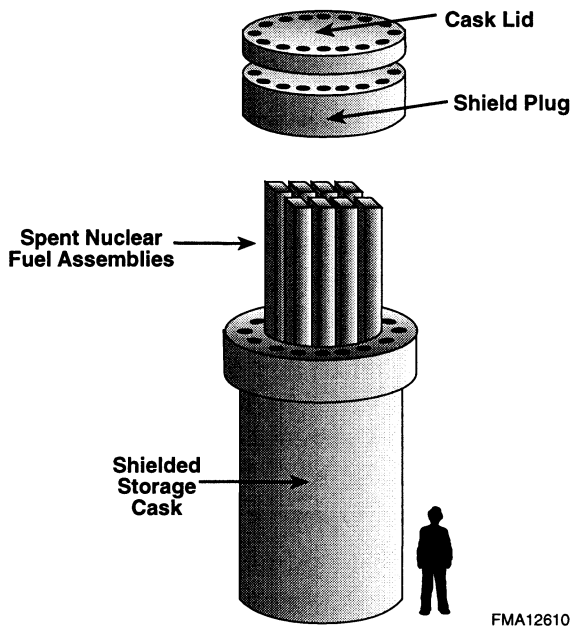

FIGURE H.1 Representative Spent Nuclear Fuel Storage Cask (Shielding is typically provided by concrete, DUCRETE [concrete with depleted UO_2], or uranium metal.)

the plant would be capable of receiving packages of depleted uranium (either UO_2 or metal) on trucks or railcars from a conversion facility, fabricating shielded casks, and storing the casks until shipment by rail to a user, such as a nuclear power plant. At the user facility, the casks would be used to store spent nuclear fuel.

The potential impacts from a manufacturing facility were analyzed for generic dry and wet environmental settings. The conditions at the dry environmental setting would be typical of a site in the western United States, and the conditions at the wet environmental setting would be typical of a site in the eastern United States.

In general, potential environmental impacts would occur (1) during construction of the cask manufacturing facility, (2) during routine operation of the cask manufacturing facility, and (3) as a result of potential manufacturing plant accidents. The potential impacts during construction would be generally limited to the duration of the construction period and would result from typical land-clearing and construction activities. Potential impacts during operations would result from handling the incoming containers of depleted uranium and from small emissions of uranium compounds to the air and water. Impacts might also occur from potential manufacturing accidents that may result in the release of hazardous materials to the environment. Impacts during the use of depleted uranium shielded casks were not quantified in the PEIS. In general, the potential impacts associated with any structural components of a depleted uranium cask would be negligible compared with the potential impacts associated with the spent nuclear fuel stored within the casks during use. Excluding accidents, no release of depleted uranium material would occur during use.

The potential environmental impacts presented in this chapter were evaluated based on the information described in the engineering analysis report (LLNL 1997). For each manufacture and use option, the engineering analysis report provides preconceptual manufacturing facility design data, including descriptions of facility layouts; shielding cask design details; resource requirements; estimates of effluents, wastes, and emissions; and descriptions of potential accident scenarios.

H.1 SUMMARY OF MANUFACTURE AND USE OPTION IMPACTS

This section provides a summary of the potential environmental impacts associated with two manufacture and use options: (1) a uranium oxide shielding option and (2) a uranium metal shielding option. The assessment of impacts was limited to the potential impacts from construction and operation of cask manufacturing facilities. Additional discussion and details related to the assessment results for individual areas of impact are provided in Section H.3.

Potential environmental impacts from the two manufacture and use options are summarized in Table H.1. Based on the information in Table H.1 and Section H.3, the following conclusions can be drawn:

- For both manufacture and use options, potential human health and safety impacts to workers and the public would be small during construction and normal operations. The consequences of accidents involving release of radioactive or chemical materials would be low. About 1 fatality during construction and operations was estimated from an on-the-job occupational accident.

- For both options, potential impacts other than human health and safety tend to be small and similar between the options.

H.2 DESCRIPTION OF OPTIONS

This section provides a brief summary of the options considered in the assessment of manufacture and use impacts. The information is based on preconceptual design data provided in the engineering analysis report (LLNL 1997). The engineering analysis report contains much more

TABLE H.1 Summary of Manufacture and Use Option Impacts

Impacts from Manufacture and Use of Oxide Shielding	Impacts from Manufacture and Use of Uranium Metal Shielding
Human Health – Normal Operations: Radiological	
Involved Workers: Total collective dose: 460 person-rem Total number of LCFs: 0.2	**Involved Workers:** Total collective dose: 100 person-rem Total number of LCFs: 0.04
Noninvolved Workers: Annual dose to MEI : $6.1 \times 10^{-5} – 2.8 \times 10^{-4}$ mrem/yr Annual cancer risk to MEI: $2 \times 10^{-11} – 1 \times 10^{-10}$ per year Total collective dose: $2.0 \times 10^{-5} – 2.5 \times 10^{-4}$ person-rem Total number of LCFs: $8 \times 10^{-9} – 1 \times 10^{-7}$ LCF	**Noninvolved Workers:** Annual dose to MEI : $1.3 \times 10^{-4} – 6.4 \times 10^{-4}$ mrem/yr Annual cancer risk to MEI: $5 \times 10^{-11} – 3 \times 10^{-10}$ per year Total collective dose : $1.2 \times 10^{-4} – 1.5 \times 10^{-3}$ person-rem Total number of LCFs: $5 \times 10^{-8} – 6 \times 10^{-7}$ LCF
General Public: Annual dose to MEI: $1.9 \times 10^{-4} – 8.7 \times 10^{-4}$ mrem/yr Annual cancer risk to MEI: $1 \times 10^{-10} – 4 \times 10^{-10}$ per year Total collective dose to population within 50 miles: 0.00098 – 0.12 person-rem Total number of LCFs in population within 50 miles: $5 \times 10^{-7} – 6 \times 10^{-5}$ LCF	**General Public:** Annual dose to MEI: $3.8 \times 10^{-4} – 1.9 \times 10^{-3}$ mrem/yr Annual cancer risk to MEI: $2 \times 10^{-10} – 1 \times 10^{-9}$ per year Total collective dose to population within 50 miles: 0.0059 – 0.73 person-rem Total number of LCFs in population within 50 miles: $3 \times 10^{-6} – 4 \times 10^{-4}$ LCF
Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts

TABLE H.1 (Cont.)

Impacts from Manufacture and Use of Oxide Shielding	Impacts from Manufacture and Use of Uranium Metal Shielding
Human Health – Accidents: Radiological	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: less than 1 in 1,000,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 0.077 rem Risk of LCF to MEI: 0.00003 per year Collective dose: 0.029 person-rem Number of LCFs: 0.00001	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.23 rem Risk of LCF to MEI: 0.00009 per year Collective dose: 0.087 person-rem Number of LCFs: 0.00003
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.0023 rem Risk of LCF to MEI: 1×10^{-6} per year Collective dose to population within 50 miles: 0.32 person-rem Number of LCFs among population within 50 miles: 0.0002 LCF	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.007 rem Risk of LCF to MEI: 4×10^{-6} per year Collective dose to population within 50 miles: 1.9 person-rem Number of LCFs among population within 50 miles: 0.001 LCF
Human Health – Accidents: Chemical	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: less than 1 in 1,000,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 0 persons Number of persons with potential for irreversible adverse effects: 0 persons	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 4 persons Number of persons with potential for irreversible adverse effects: 2 persons
General Public: Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 0 persons Number of persons with potential for irreversible adverse effects: 0 persons	**General Public:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 1 person Number of persons with potential for irreversible adverse effects: 1 person

TABLE H.1 (Cont.)

Impacts from Manufacture and Use of Oxide Shielding	Impacts from Manufacture and Use of Uranium Metal Shielding
Human Health — Accidents: Physical Hazards	
Construction and Operations: **All Workers:** Approximately 1 fatality, approximately 640 injuries	**Construction and Operations:** **All Workers:** Approximately 1 fatality, approximately 670 injuries
Air Quality	
Construction: Concentrations of criteria pollutants all 9% or less of respective standards	**Construction:** Concentrations of criteria pollutants all 9% or less of respective standards
Operations: Pollutant concentrations 4% or less of values during construction	**Operations:** Pollutant concentrations 4% or less of values during construction
Water[a]	
Construction: Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater
Operations: None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater
Soil[a]	
Construction: Negligible but temporary impacts	**Construction:** Negligible but temporary impacts
Operations: No impacts	**Operations:** No impacts
Socioeconomics	
Construction: Potentially moderate impacts on employment and income	**Construction:** Potentially moderate impacts on employment and income
Operations: Potentially moderate impacts on employment and income	**Operations:** Potentially moderate impacts on employment and income
Ecology	
Construction: Potential moderate impacts to vegetation and wildlife	**Construction:** Potential moderate impacts to vegetation and wildlife
Operations: Negligible impacts	**Operations:** Negligible impacts
Waste Management	
Negligible impacts on regional or national waste management operations	Negligible impacts on regional or national waste management operations

TABLE H.1 (Cont.)

Impacts from Manufacture and Use of Oxide Shielding	Impacts from Manufacture and Use of Uranium Metal Shielding
Resource Requirements	
No impacts from resource requirements (such as electricity or materials) would be expected on the local or national scale	No impacts from resource requirements (such as electricity or materials) would be expected on the local or national scale
Land Use	
Use of approximately 90 acres; potential moderate impacts, including traffic impacts	Use of approximately 90 acres; potential moderate impacts, including traffic impacts

[a] Impacts if the generic site was large relative to the proposed facility and was located near a river where minimum flow was large relative to water use.

Notation: LCF = latent cancer fatality; MEI = maximally exposed individual; PM_{10} = particulate matter with a mean diameter of 10 µm or less; ROI = region of influence.

detailed information, including descriptions of manufacturing facility layouts; shielding cask design details; resource requirements; estimates of effluents, wastes, and emissions; and descriptions of potential accident scenarios. The manufacture and use options assume that depleted uranium in the form of UO_2 or metal would be shipped to the manufacturing plant from a conversion facility. The environmental impacts associated with the conversion process are provided in Appendix F.

H.2.1 Uranium Oxide Shielding Option

The uranium oxide shielding option would require a total site area of about 90 acres (37 ha), of which 32 acres (13 ha) would be disturbed or cleared. The manufacturing facility would receive high-density UO_2 from a conversion plant, and the partially fabricated stainless steel shells and other shielding cask components from a supplier. The steel cask shell would be fabricated using conventional industry practices, including welding, machining and final assembly. At the cask manufacturing facility, uranium oxide shielding would be prepared using high-shear mixing for evenly combining the high-density UO_2 and concrete components. The mixture would then be poured between an inner and outer steel cask shell. Final assembly of the shielding cask would be performed after the mixture cured. The oxide shielding composition would be nominally 74% UO_2, 11% sand, 10% cement and additives, and the remainder water. Each cask would contain about 50 tons (45 metric tons) of UO_2, with about 480 casks being manufactured each year. The casks would then be sent to a user, such as a nuclear power plant.

H.2.2 Uranium Metal Shielding Option

The metal shielding option would require a total site area of about 90 acres (37 ha), of which 36 acres (15 ha) would be disturbed or cleared. The manufacturing facility would receive uranium metal ingots (or alloy) from a conversion plant, and partially fabricated stainless steel or titanium alloy shells and other shielding cask components from a supplier. The inner and outer steel shells of the casks would be assembled using standard operations, such as welding, machining and final assembly. In a separate building, the uranium metal would be melted and directly cast between the inner and outer shells of the assembled cask. After cooling, final assembly of the shielding cask would be carried out. Each finished shielding cask would contain about 47 tons (43 metric tons) of uranium metal, with about 453 casks being manufactured each year.

H.2.3 Manufacture and Use Options Considered But Not Analyzed

Several manufacture and use options were not analyzed in depth in the engineering analysis report: (1) use of depleted uranium in light water reactor fuel, (2) use of depleted uranium as fuel in advanced breeder reactors, and (3) dense material applications other than radiation shielding. As discussed more fully in Section 2.3.2 of the PEIS, these uses are either too uncertain at this time for full analysis or are represented by the options analyzed in the PEIS.

H.3 IMPACTS OF OPTIONS

This section provides a summary of the potential environmental impacts associated with the manufacture and use options, including impacts from construction and facility operations. Information related to the assessment methodologies for each area of impact is provided in Appendix C.

The environmental impacts from the manufacture and use options were evaluated based on the information described in the engineering analysis report (LLNL 1997). The following general assumptions apply to the assessment of impacts:

- Shielding cask manufacturing facilities would operate over a 20-year period, from 2009 through 2028, using either depleted uranium oxide or metal from the DOE-generated inventory. Preoperation of manufacturing facilities would occur between 1999 and 2008, with actual construction requiring 7 years.

- The uranium oxide and uranium metal cask manufacturing plants would produce 480 and 453 casks per year, respectively, over the operational period.

- The cask manufacturing facilities were assumed to be stand-alone facilities built for the specific purpose of fabricating casks. The manufacturing facilities would receive depleted uranium in the form of UO_2 or metal from a conversion facility.

- Potential impacts from a manufacturing facility were analyzed for generic dry and wet environmental settings and for generic rural and urban settings. The historical meteorological conditions for five actual “dry” locations in the southwestern United States and five actual “wet” locations in the central and southeastern United States were averaged to develop estimates for the generic settings. The generic rural setting was assumed to have a population density corresponding to 15 persons/mi^2 (6 persons/km^2); the generic urban setting was assumed to have a population density corresponding to 700 persons/mi^2 (275 persons/km^2).

- The assessment of impacts was limited to potential impacts from the construction and operation of a cask manufacturing facility. Impacts during the use of depleted uranium shielded casks have not been estimated in the PEIS because the impacts associated with the depleted uranium cask components would be negligible compared with the potential impacts associated with the spent nuclear fuel within a cask and because no release of depleted uranium material would occur during use. Use of spent nuclear fuel storage casks would be subject to DOE or U.S. Nuclear Regulatory Commission (NRC) review and approval.

- The impacts presented herein for manufacturing of oxide- and metal-shielded containers would be representative of any impacts associated with manufacture of other products that contain depleted uranium because none of the other potential uses would consume as much depleted UF_6 inventory as the oxide and metal container use.

- Because of existing regulations in the United States, it is highly unlikely that products containing depleted uranium would be available for unrestricted use at this time. Impacts to the general public from restricted use applications would be negligible. Impacts to the workers from uranium oxide or uranium metal casks at the user locations (e.g., commercial nuclear power generators) would depend largely on the particular application but would be less than those to workers at the manufacturing facilities. Any commercial use of depleted uranium would take place under an NRC license or a waiver from the NRC. Potential impacts from such use would have to be analyzed before a license or waiver could be obtained.

H.3.1 Human Health — Normal Operations

H.3.1.1 Radiological Impacts

Radiological impacts were assessed for involved workers, noninvolved workers, and the general public. Impacts to involved workers would result primarily from exposures to external radiation in the vicinity of uranium material for both options considered. The average radiation dose would be less than 110 mrem/yr. Impacts to noninvolved workers and the general public would result from release of uranium compounds to the environment. The maximum radiation dose would be very small, less than 0.002 mrem/yr. The estimated radiation doses and cancer risks are listed in Tables H.2 and H.3, respectively. Detailed discussions of the methodologies used in radiological impact analyses are provided in Appendix C and Cheng et al. (1997).

TABLE H.2 Radiological Doses from Manufacture and Use Options under Normal Operations

	Dose to Receptor[a]					
	Involved Worker[b]		Noninvolved Worker[c]		General Public	
Shielding Option	Average Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose[d] (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose[e] (mrem/yr)	Collective Dose[f] (person-rem/yr)
Uranium oxide casks	110	23	6.1×10^{-5} – 2.8×10^{-4}	1.0×10^{-6} – 1.2×10^{-5}	1.9×10^{-4} – 8.7×10^{-4}	4.9×10^{-5} – 6.1×10^{-3}
Uranium metal casks	23	5.0	1.3×10^{-4} – 6.4×10^{-4}	6.2×10^{-6} – 7.5×10^{-5}	3.8×10^{-4} – 1.9×10^{-3}	3.0×10^{-4} – 3.7×10^{-2}

a Impacts are reported as ranges, which result from differences for five generic dry and wet environmental settings.

b Involved workers are those workers directly involved with the handling of materials. Results are presented as average individual dose and collective dose for the worker population. Radiation doses to individual workers would be monitored by a dosimetry program and maintained below applicable standards, such as the DOE administrative control limit of 2,000 mrem/yr.

c Noninvolved workers are individuals who do not participate in material-handling activities, such as managers and secretaries. The number of noninvolved workers would be about 200 for both uranium oxide casks and uranium metal casks.

d The MEI for the noninvolved workers was assumed to be located on-site at the location that would yield the largest dose from airborne emissions, including doses from inhalation, external radiation, and incidental ingestion of soil.

e The MEI for the general public was assumed to be located off-site at the point that would yield the largest dose from exposures through inhalation, external radiation, and ingestion of plant foods, meat, milk, soil, and drinking water.

f The collective dose was estimated for the off-site population within a 50-mile (80-km) radius around the facility. The range of collective doses results from differences in dry and wet locations surrounded by a rural (about 120,000 people) or urban (about 5,600,000 people) population. The exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk and soil.

TABLE H.3 Latent Cancer Risks from Manufacture and Use Options under Normal Operations

	Risk to Receptor[a]					
	Involved Worker[b]		Noninvolved Worker[c]		General Public	
Shielding Option	Average Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk[d] (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk[e] (risk/yr)	Collective Risk[f] (fatalities/yr)
Uranium oxide casks	4×10^{-5}	9×10^{-3}	2×10^{-11} – 1×10^{-10}	4×10^{-10} – 5×10^{-9}	1×10^{-10} – 4×10^{-10}	2×10^{-8} – 3×10^{-6}
Uranium metal casks	9×10^{-6}	2×10^{-3}	5×10^{-11} – 3×10^{-10}	2×10^{-9} – 3×10^{-8}	2×10^{-10} – 1×10^{-9}	2×10^{-7} – 2×10^{-5}

[a] Impacts are reported as ranges, which result from differences for five generic dry and wet environmental settings.

[b] Involved workers are those workers directly involved with the handling of materials. Results are presented as average individual risk and collective risk for the worker population.

[c] Noninvolved workers are individuals who do not participate in material-handling activities, such as managers and secretaries. The number of noninvolved workers is about 200 for both uranium oxide casks and uranium metal casks.

[d] The MEI for the noninvolved workers was assumed to be located on-site at the location that would yield the largest risk from airborne emissions, including risks from inhalation, external radiation, and incidental ingestion of soil.

[e] The MEI for the general public was assumed to be located off-site at the point that would yield the largest risk from exposures through inhalation, external radiation, and ingestion of plant foods, meat, milk, soil, and drinking water.

[f] The collective risk was estimated for the population within a 50-mile (80-km) radius around the facility. The range of collective risks results from differences in dry and wet locations surrounded by a rural (about 120,000 people) or urban (about 5,600,000 people) population. The exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk and soil.

H.3.1.1.1 Impacts from Manufacturing

Uranium Oxide. For the uranium oxide option, the collective dose to involved workers was estimated to be approximately 23 person-rem/yr for a total of 220 workers, which corresponds to about 0.009 additional latent cancer fatality (LCF) per year among workers (i.e., 1 LCF would be expected in 110 years of operation). The average involved worker dose was estimated to be about 110 mrem/yr, well below the regulatory limit of 5,000 mrem/yr specified for workers (10 *Code of Federal Regulations* [CFR] Part 835). The average risk to an involved worker of developing an LCF would be about 4×10^{-5} per year (one chance in 25,000 per year).

Radiation doses to noninvolved workers and members of the general public would depend on the location of the facility and would be very small because of the small amount of uranium released. The radiation dose to the maximally exposed individual (MEI) of noninvolved workers would be less than 2.8×10^{-4} mrem/yr, whereas the dose to the MEI of the general public would be less than 8.7×10^{-4} mrem/yr.

Uranium Metal. Because of the smaller volume handled and better self shielding characteristics of uranium metal (the density of uranium metal is about twice that of uranium oxide), the manufacturing of uranium metal casks would result in less radiation exposures to involved workers than the manufacturing of uranium oxide casks. The collective dose to involved workers was estimated to be about 5.0 person-rem/yr for approximately 220 workers. The average dose received by an involved worker would be about 23 mrem/yr, corresponding to an LCF risk of 9×10^{-6} per year (1 chance in 110,000 per year).

Radiation exposures to noninvolved workers and members of the general public from the uranium metal facility would be greater than those from the uranium oxide facility because of the higher emission rate of uranium. However, the radiation doses to the MEIs would be very small, less than 6.4×10^{-4} mrem/yr for noninvolved workers and less than 1.9×10^{-3} mrem/yr for the general public.

H.3.1.1.2 Impacts from Use

The spent nuclear fuel shielding casks made with uranium metal or uranium oxide would have the same shielding capability as conventional casks made with concrete, lead, or other shielding material. Although depleted uranium would be incorporated into the manufactured casks, the resulting exposure to personnel from the depleted uranium would be negligible when compared with the exposures from the spent nuclear fuel stored in the cask.

H.3.1.2 Chemical Impacts

Potential chemical impacts to human health from normal operations would result primarily from uranium releases from the manufacturing facilities. Risks from normal operations were quantified on the basis of calculated hazard indexes. Information on the exposure assumptions, health effects assumptions, reference doses used for uranium compounds, and calculational methods used in the chemical impact analysis is provided in Appendix C and Cheng et al. (1997).

H.3.1.2.1 Impacts from Manufacturing

Airborne emissions of uranium compounds from the metal facility would be more than 5 times greater than uranium emissions from the uranium oxide facility (LLNL 1997). Therefore, chemical exposures for the noninvolved workers and off-site general public would be higher due to releases from the metal facility. However, human health impacts would still be negligible for the noninvolved workers and off-site public for both manufacture and use options.

Uranium Oxide. Estimates of the impacts to human health from hazardous chemicals during operations at the uranium oxide facility are summarized in Table H.4. The overall hazard indices for chemical impacts to the noninvolved worker MEI were estimated to be less than

TABLE H.4 Chemical Impacts to Human Health from Manufacture and Use Options under Normal Operations

	Impacts to Receptor[a]			
	Noninvolved Workers[b]		General Public	
Shielding Option	Hazard Index for MEI[c,d]	Collective Risk[e] (ind. at risk/yr)	Hazard Index for MEI[c,f]	Collective Risk[e] (ind. at risk/yr)
Uranium oxide casks	$7.7 \times 10^{-9} - 3.4 \times 10^{-8}$	–	$6.2 \times 10^{-7} - 2.9 \times 10^{-6}$	–
Uranium metal casks	$1.6 \times 10^{-8} - 7.9 \times 10^{-8}$	–	$1.4 \times 10^{-6} - 6.7 \times 10^{-6}$	–

[a] Impacts are reported as ranges, which result from differences for five generic dry and wet environmental settings.

[b] Noninvolved workers are individuals who do not participate in material-handling activities, such as managers and secretaries.

[c] The hazard index is an indicator for potential health effects other than cancer; a hazard index greater than 1 indicates a potential for adverse health effects and a need for further evaluation.

[d] The MEI for the noninvolved workers was assumed to be located on-site at the location that would yield the largest exposure from airborne emissions, including exposures through inhalation and incidental ingestion of soil.

[e] Calculation of collective risk is not applicable when the corresponding hazard index for the MEI is less than 1.

[f] The MEI for the general public was assumed to be located off-site at the point that would yield the largest exposures through inhalation and ingestion of soil and drinking water.

3.4×10^{-8} for all dry and wet representative locations. Because these values are considerably below the threshold for adverse effects (i.e., the ratio of intake to reference dose is less than 1), no health effects would be expected. The overall hazard indices for chemical impacts to the general public MEI are estimated to be less than 2.9×10^{-6} for all dry and wet representative sites. These values are also considerably below the threshold for adverse effects.

Uranium Metal. Estimates of the hazardous chemical human health impacts resulting from operations at the uranium metal facility are summarized in Table H.4. Hazard indices are approximately 2 times higher for the uranium metal option than for the uranium oxide option but still many orders of magnitude below the threshold for adverse effects.

H.3.1.2.2 Impacts from Use

Only the operations of the two types of manufacturing facilities would result in airborne and waterborne emissions of uranium; the use of shielding casks made with uranium metal or uranium oxide would not be expected to release any materials and, therefore, would not result in any impacts to the noninvolved workers and general public.

H.3.2 Human Health — Accident Conditions

A range of accidents covering the spectrum of high-frequency/low-consequence accidents to low-frequency/high-consequence accidents has been presented in the engineering analysis report (LLNL 1997). These accidents are listed in Table H.5. The following sections present the results for the radiological and chemical health impacts of the highest consequence accident in each frequency category. Results for all accidents listed in Table H.5 are presented in Policastro et al. (1997). A detailed description of the methodology and assumptions used in the calculations is also provided in Appendix C and Policastro et al. (1997).

H.3.2.1 Radiological Impacts

The radiological doses to various receptors for the accidents that give the highest dose from each frequency category are listed in Table H.6. The LCF risks for these accidents are given in Table H.7. The doses and the risks are presented as ranges (maximum and minimum) because two different meteorological conditions (wet and dry) and two different population distributions (rural and urban) were considered for each manufacture and use option. The doses and risks presented here were obtained by assuming that the accidents would occur. The probability of occurrence for each accident is indicated by the frequency category to which it belongs. For example, accidents in the extremely unlikely category have a probability of occurrence between 1 in 10,000 and 1 in 1 million in any 1 year. The following conclusions may be drawn from the radiological health impact results:

- No cancer fatalities would be predicted from any of the accidents.

- The maximum radiological dose to noninvolved worker and general public MEIs (assuming an accident occurred) would be 230 mrem. This dose is less than the 25-rem dose recommended for assessing the adequacy of protection of public health and safety from potential accidents by the NRC (1994).

- The overall radiological risk to noninvolved worker and general public MEI receptors (estimated by multiplying the risk per occurrence [Table H.7] by the annual probability of occurrence by the number of years of operations) would be less than 1 for all of the manufacture and use accidents.

H.3.2.2 Chemical Impacts

The accidents considered in this section are listed in Table H.5. The results of the accident consequence modeling in terms of chemical impacts are presented in Tables H.8 and H.9. The results are expressed as (1) number of persons with potential for adverse effects and (2) number of persons with potential for irreversible adverse effects. The tables present the results for the accident within each frequency category that would affect the largest number of people (total of noninvolved workers and population) (Policastro et al. 1997). The numbers of noninvolved workers and members of the

TABLE H.5 Accidents Considered for the Manufacture and Use Options

Option/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Manufacture and Use as Oxide Shielding					
Likely Accidents (frequency: 1 or more times in 100 years)					
Mishandling/drop of drum/billet inside the plant	A single UO_2 drum is damaged by a forklift and spills its contents onto the ground inside the UO_2 cask manufacturing plant.	UO_2	7.3×10^{-7}	Puff	Stack
Mixer/melter charge accident	Mishandling of the input load to the oxide mixer results in an airborne release of the input drum contents.	UO_2	0.000073	Puff	Stack
Mixer/melter operational accident	Failure of the oxide mixer during operation results in an airborne release of the mixer contents.	UO_2	0.00015	Puff	Stack
Mixer/melter discharge accident	Failure during discharge of the oxide mixers results in an airborne release.	UO_2	0.00044	Puff	Stack
Shield failure after casting	After the cask annulus has been filled with depleted uranium, it fails due to rupture or chemical reactivity.	UO_2	9.7×10^{-6}	Puff	Stack
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Earthquake	The UO_2 cask manufacturing plant is damaged during a design-basis earthquake, resulting in failure of the structure and confinement systems.	UO_2	0.33	30	Ground
Tornado	A major tornado and associated tornado missiles result in failure of the UO_2 cask manufacturing plant structure and confinement systems.	UO_2	1.6	0.5	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Fire/explosion/chemical reagent contact inside the mixers	A leak or rupture of the oxide mixers results in a fire and/or explosion, but the HEPA filtration system is not affected.	UO_2	0.00044	Puff	Stack
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA

TABLE H.5 (Cont.)

Option/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Manufacture and Use as Metal Shielding					
Likely Accidents (frequency: 1 or more times in 100 years)					
Mishandling/drop of drum/billet inside the plant	A pallet of uranium metal billets is damaged by a forklift and spills its contents onto the ground inside the uranium metal cask manufacturing plant.	U_3O_8	0.0012	Puff	Stack
Mixer/melter charge accident	Mishandling of the input load to the uranium furnace results in an airborne release of the input billets.	U_3O_8	0.00009	Puff	Stack
Mixer/melter operational accident	Failure of the uranium furnace during operation results in an airborne release of the furnace contents.	U_3O_8	0.0004	Puff	Stack
Mixer/melter discharge accident	Failure during discharge of the uranium furnace results in an airborne release.	U_3O_8	0.0004	Puff	Stack
Shield failure after casting	After the cask annulus has been filled with molten depleted uranium it fails due to rupture or chemical reactivity.	U_3O_8	0.00059	Puff	Stack
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Earthquake	The uranium metal cask manufacturing plant is damaged during a design-basis earthquake, resulting in failure of the structure and confinement systems.	U_3O_8	0.05	30	Ground
Tornado	A major tornado and associated tornado missiles result in failure of the uranium metal cask manufacturing plant structure and confinement systems.	U_3O_8	0.05	0.5	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Fire/explosion/chemical reagent contact inside the cask annulus	The molten uranium within a cask annulus is oxidized, resulting in a fire and/or explosion, but the HEPA filtration system is not affected.	U_3O_8	0.0059	Puff	Stack
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA
Uranium metal furnace failure	A large seismic event or beyond-design-basis event causes failure of eight furnaces feeding one cask.	UO_2	35	Puff	Ground

[a] Ground-level releases were assumed to occur outdoors on concrete pads in the cylinder storage yards. To prevent contaminant migration, cleanup of residuals was assumed to begin immediately after the release was stopped.

Notation: HEPA = high-efficiency particulate air; NA = not applicable; UO_2 = uranium dioxide; U_3O_8 = triuranium octaoxide.

TABLE H.6 Estimated Radiological Doses per Accident Occurrence for the Manufacture and Use Options

		Maximum Dose[c]				Minimum Dose[c]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Option/Accident[a]	Frequency Category[b]	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)
Manufacture and Use as Oxide Shielding									
Mixer/melter discharge accident	L	1.5×10^{-8}	1.3×10^{-7}	1.5×10^{-8}	2.7×10^{-5}	4.5×10^{-12}	3.6×10^{-11}	7.6×10^{-10}	2.7×10^{-7}
Earthquake	U	7.7×10^{-2}	2.9×10^{-2}	2.3×10^{-3}	3.2×10^{-1}	3.2×10^{-3}	1.2×10^{-3}	9.2×10^{-5}	1.1×10^{-3}
Fire/explosion/chemical reagent contact inside the mixers	EU	1.5×10^{-8}	1.2×10^{-7}	1.5×10^{-8}	2.7×10^{-5}	4.4×10^{-12}	3.6×10^{-11}	7.5×10^{-10}	2.7×10^{-7}
Manufacture and Use as Metal Shielding									
Mishandling/drop of drum/billet inside	L	3.9×10^{-8}	3.3×10^{-7}	4.0×10^{-8}	7.0×10^{-5}	1.2×10^{-11}	9.4×10^{-11}	2.0×10^{-9}	7.1×10^{-7}
Earthquake	U	1.1×10^{-2}	4.3×10^{-3}	3.4×10^{-4}	4.6×10^{-2}	4.7×10^{-4}	1.8×10^{-4}	1.3×10^{-5}	1.6×10^{-4}
Fire/explosion/chemical reagent contact inside the cask annulus	EU	1.9×10^{-7}	1.6×10^{-6}	2.0×10^{-7}	3.5×10^{-4}	5.8×10^{-11}	4.7×10^{-10}	9.8×10^{-9}	3.5×10^{-6}
Uranium metal furnace failure	I	2.3×10^{-1}	8.7×10^{-2}	7.0×10^{-3}	1.9	2.3×10^{-1}	8.7×10^{-2}	5.5×10^{-3}	4.2×10^{-2}

[a] The bounding accident chosen to represent each frequency category is the one that would result in the highest dose to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[b] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($>10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($<10^{-6}$/yr).

[c] Maximium and minimum doses reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum doses would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum doses would occur under D stability with 4 m/s wind speed.

TABLE H.7 Estimated Radiological Health Risks per Accident Occurrence for the Manufacture and Use Options[a]

Option/Accident[b]	Frequency Category[c]	Maximum Risk[d] (LCFs)				Minimum Risk[d] (LCFs)			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
		MEI	Population	MEI	Population	MEI	Population	MEI	Population
Manufacture and Use as Oxide Shielding									
Mixer/melter discharge accident	L	6×10^{-12}	5×10^{-11}	8×10^{-12}	1×10^{-8}	2×10^{-15}	1×10^{-14}	4×10^{-13}	1×10^{-10}
Earthquake	U	3×10^{-5}	1×10^{-5}	1×10^{-6}	2×10^{-4}	1×10^{-6}	5×10^{-7}	5×10^{-8}	5×10^{-7}
Fire/explosion/chemical reagent contact inside the mixers	EU	6×10^{-12}	5×10^{-11}	8×10^{-12}	1×10^{-8}	2×10^{-15}	1×10^{-14}	4×10^{-13}	1×10^{-10}
Manufacture and Use as Metal Shielding									
Mishandling/drop of drum/billet inside	L	2×10^{-11}	1×10^{-10}	2×10^{-11}	4×10^{-8}	5×10^{-15}	4×10^{-14}	1×10^{-12}	4×10^{-10}
Earthquake	U	4×10^{-6}	2×10^{-6}	2×10^{-7}	2×10^{-5}	2×10^{-7}	7×10^{-8}	7×10^{-9}	8×10^{-8}
Fire/explosion/chemical contact reagent inside the cask annulus	EU	8×10^{-11}	7×10^{-10}	1×10^{-10}	2×10^{-7}	2×10^{-14}	2×10^{-13}	5×10^{-12}	2×10^{-9}
Uranium metal furnace failure	I	9×10^{-5}	3×10^{-5}	4×10^{-6}	1×10^{-3}	9×10^{-5}	3×10^{-5}	3×10^{-6}	2×10^{-5}

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (LCF) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one that would result in the highest risk to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[d] Maximum and minimum risks reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

TABLE H.8 Number of Persons with Potential for Adverse Effects from Accidents under the Manufacture and Use Options[a]

		Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Option/Accident[b]	Frequency Category[c]	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Manufacture and Use as Oxide Shielding									
Mixer/melter discharge accident[f]	L	No	0	No/No	0/0	No	0	No/No	0/0
Tornado[f,g]	U	No	0	No/No	0/0	NA	NA	NA	NA
Fire/explosion/chemical reagent contact inside mixers[f]	EU	No	0	No/No	0/0	No	0	No/No	0/0
Manufacture and Use as Metal Shielding									
Mishandle/drop of drum/billet inside[f]	L	No	0	No/No	0/0	No	0	No/No	0/0
Earthquake	U	No	0	No/No	0/0	No	0	No/No	0/0
Fire/explosion/chemical reagent contact inside cask annulus[f]	EU	No	0	No/No	0/0	No	0	No/No	0/0
Uranium metal furnace failure	I	Yes	4	No/Yes	0/1	Yes[h]	0	No/Yes[h]	0/0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site people) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

[d] Maximum and minimum values reflect different meteorological conditions at the time of the accidents. In general, maximum risks would occur under meteorological conditions of F stability and 1 m/s wind speed, whereas minimum risks would occur under D stability and 4 m/s wind speed. Results for the general public MEI are for rural/urban locations, respectively.

[e] At the MEI location, the determination is either "Yes" or "No" for potential adverse effects to an individual.

[f] These accidents would result in the largest plume sizes, although no people would be affected.

[g] Meteorological conditions for the tornado scenario were considered to be D stability with 20 m/s wind speed. NA = not applicable.

[h] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because generic worker and general public population distributions were used, which did not show receptors at the MEI locations.

TABLE H.9 Number of Persons with Potential for Irreversible Adverse Effects from Accidents under the Manufacture and Use Options[a]

Option/Accident[b]	Frequency Category[c]	Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
		MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Manufacture and Use as Oxide Shielding									
Mixer/melter discharge accident[f]	L	No	0	No/No	0/0	No	0	No/No	0/0
Tornado[f,g]	U	No	0	No/No	0/0	NA	NA	NA	NA
For/explosion/chemical reagent contact inside mixers[f]	EU	No	0	No/No	0/0	No	0	No/No	0/0
Manufacture and Use as Metal Shielding									
Mishandle/drop of drum/billet inside[f]	L	No	0	No/No	0/0	No	0	No/No	0/0
Earthquake[f]	U	No	0	No/No	0/0	No	0	No/No	0/0
Fire/explosion/chemical reagent contact inside cask annulus[f]	EU	No	0	No/No	0/0	No	0	No/No	0/0
Uranium metal furnace failure	I	Yes	2	No/Yes	0/0	No	0	No/Yes[h]	0/0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site people) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} – 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} – 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

[d] Maximum and minimum values reflect different meteorological conditions at the time of the accidents. In general, maximum risks would occur under meteorological conditions of F stability and 1 m/s wind speed, whereas minimum risks would occur under D stability and 4 m/s wind speed. Results for the general public MEI are for rural/urban locations, respectively.

[e] At the MEI location, the determination is either "Yes" or "No" for potential irreversible adverse effects to an individual.

[f] These accidents would result in the largest plume sizes, although no people would be affected.

[g] Meteorological conditions for the tornado scenario were considered to be D stability with 20 m/s wind speed. NA = not applicable.

[h] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because generic worker and general public population distributions were used, which did not show receptors at the MEI locations.

off-site public represent the impacts if the associated accident was assumed to occur. These results of the chemical impact analysis may be summarized as follows:

- If the accidents identified in Tables H.8 and H.9 did occur, the number of persons in the off-site population with potential for adverse effects would range from 0 to 1, and the number of off-site persons with potential for irreversible adverse effects would range from 0 to 1 (maximums corresponding to failure of the uranium metal furnace).

- If the accidents identified in Tables H.8 and H.9 did occur, the number of noninvolved workers with potential for adverse effects would range from 0 to 4, and the number of nonvinvolved workers with potential for irreversible adverse effects would range from 0 to 2 (maximums corresponding to failure of the uranium metal furnace).

- The impacts for the uranium metal shielding option would be slightly higher than those for uranium oxide applications. However, the overall impacts for the manufacture and use options would be very small compared with other options.

- For the most severe accident (uranium metal furnace failure), the noninvolved worker MEI would experience potential adverse effects and potential irreversible adverse effects, whereas the general public MEI would experience no adverse impacts at the rural site. If an urban site were chosen for this activity, a small number of both the noninvolved worker and the public MEIs could be affected in terms of both health criteria. The reduced impacts to the public MEI compared with the worker MEI were based on dispersion of the chemical release with downwind distance. For the other accidents assessed, neither the worker nor the public MEI would experience adverse effects.

- The maximum risk was computed as the product of the consequence (number of people) times the frequency of occurrence (per year) times the number of years of operations (20 years, 2009–2028). The results indicated that the maximum risk values would be less than 1 for all accidents.

To aid in the interpretation of accident analysis results, the number of fatalities potentially associated with the estimated potential irreversible adverse effects was estimated. All the bounding case accidents shown in Table H.9 would involve small releases of uranium oxide and potential exposure to uranium compounds. If the accidents occurred, exposures are estimated to result in death for 1% or less of the persons experiencing irreversible adverse effects (Policastro et al. 1997). Thus, for workers and members of the general public experiencing ranges of 0 to 2 and 0 to 1 irreversible adverse effects, respectively, 0 deaths would be expected.

H.3.2.3 Physical Hazards

The risk of on-the-job fatalities and injuries to all manufacturing facility workers from the fabrication of uranium oxide and uranium metal shielding was calculated using industry-specific statistics from the U.S. Bureau of Labor Statistics, as reported by the National Safety Council (1995). Construction and manufacturing annual fatality and injury rates were used for the construction and operational phases, respectively, of the manufacturing facility lifetime.

Because manufacturing activities would be quite labor-intensive, relatively high injury incidence rates are predicted, with about one fatality expected over the lifetime of facility operations. There is little difference in impacts between the uranium oxide and metal shielding options, although the fatality and incidence rates for the metal option would be slightly higher.

The estimated number of worker fatalities for the uranium oxide shielding option is 0.76 for the construction and operational phases combined (Table H.10). The estimated number of injuries over the lifetime of the uranium oxide facility is about 640.

The estimated number of worker fatalities for the uranium metal shielding option is 0.85 for the construction and operational phases combined (Table H.10). The estimated number of injuries over the lifetime of the metal facility is about 670.

TABLE H.10 Potential Impacts to Human Health from Physical Hazards under Accident Conditions for the Manufacture and Use Options

	Impacts to All Manufacturing Facility Workers[a]			
	Incidence of Fatalities[b]		Incidence of Injuries[b]	
Shielding Option	Construction	Operations	Construction	Operations
Uranium oxide casks	0.38	0.38	140	500
Uranium metal casks	0.48	0.37	180	490

[a] All construction and operational workers at the manufacturing facilities were included in physical hazard risk calculations.

[b] The incidence of fatalities and incidence of injuries were calculated as the number of full-time-equivalent employees times the annual fatality rate times the number of years. Only injuries involving lost workdays were estimated. Injury and fatality incidence rates used in the calculations were taken from National Safety Council (1995).

H.3.3 Air Quality

The methodology used to analyze the air quality impacts from both uranium oxide and uranium metal manufacturing and use options is provided in Appendix C and Tschanz (1997). The pollutant concentrations at several distances from the center of the facility were estimated because of uncertainty regarding the size and location of the generic manufacturing facility. Estimates at 750 m from the center of the manufacturing facilities are comparable to estimates for options based on representative environmental settings (i.e., conversion and long-term storage options using the three current storage sites as representative of those settings).

For both options, by far the largest emissions, and hence impacts on air quality, would occur during construction of the manufacturing facility. Table H.11 presents a comparison of some of the pollutant impacts from construction of the two types of manufacturing facilities at a generic wet environmental setting. The estimated pollutant concentrations — carbon monoxide (CO), nitrogen oxides (NO_x), and PM_{10} (particulate matter with a mean diameter of 10 µm or less) — are all 9% or less of the applicable air quality standards, even at the closest distance from the emissions point. The ranges of impacts for the generic wet setting (as represented by the results in Table H.11) are greater than those estimated for a generic dry setting, and the uncertainties of the wet setting impacts are also greater.

The area source emissions during operation of the manufacturing facility for either option would be smaller than during construction. For both types of facility, operations would emit about 4% as much CO and NO_x and about 1.4% as much PM_{10} as would be emitted during construction. The impacts from these low emissions would be negligible.

The quantities of uranium oxide emitted during operation of either manufacturing facility are estimated to be quite small. The uranium oxide facility would emit only 8 g/yr of uranium as UO_2, which corresponds to an annual average concentration of about 1.6×10^{-7} µg/m^3 at a distance of 3,300 ft (1,000 m). The approximately 50 g/yr of uranium in triuranium octaoxide (U_3O_8) emitted by the uranium metal facility would produce an annual average uranium concentration of 9.9×10^{-7} µg/m^3 at 3,300 ft (1,000 m). Impacts on air quality would be negligible for both options.

No quantitative estimate was made of the impacts of operations on ozone conditions in the atmosphere. Ozone formation is a regional issue that would be affected by emissions for the entire area around a proposed manufacturing site. The pollutants most relevant to ozone formation that would result from the manufacturing options are hydrocarbons (HC) and NO_x. In later Phase II studies, when specific technologies and sites would be selected, the potential effects of these pollutants released from a proposed facility at a specific site could be evaluated relative to the total emissions of HC and NO_x in the surrounding area. Small additional contributions to the total regional emissions would be unlikely to alter the ozone attainment status of the region.

TABLE H.11 Estimated Pollutant Emissions during Construction of a Shielding Manufacturing Facility in a Wet Environmental Setting[a]

Option/ Pollutant Distance/ from Source	Estimated Maximum Pollutant Emissions[b]							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
	Range ($\mu g/m^3$)	Fraction of Standard[c]	Range ($\mu g/m^3$)	Fraction of Standard[c]	Range ($\mu g/m^3$)	Fraction of Standard[c]	Range ($\mu g/m^3$)	Fraction of Standard[c]
Uranium oxide								
CO								
750 m	78 – 150	0.0038	13 – 30	0.0030	–	–	–	–
1,000 m	71 –120	0.0030	10 – 23	0.0023	–	–	–	–
1,500 m	58 – 89	0.0022	6.5 – 14	0.0014	–	–	–	–
NO_x								
750 m	–	–	–	–	–	–	3.3 – 8.5	0.085
1,000 m	–	–	–	–	–	–	1.8 – 4.6	0.046
1,500 m	–	–	–	–	–	–	0.60 – 2.2	0.022
PM_{10}								
750 m	–	–	–	–	1.8 – 4.6	0.031	0.25 – 0.61	0.012
1,000 m	–	–	–	–	1.4 – 3.3	0.022	0.13 – 0.33	0.0066
1,500 m	–	–	–	–	0.81 – 2.2	0.015	0.062 – 0.16	0.0032
Uranium metal								
CO								
750 m	83 – 160	0.0040	14 – 32	0.0032	–	–	–	–
1,000 m	76 – 128	0.0032	11 – 24	0.0024	–	–	–	–
1,500 m	62 – 95	0.0024	6.9 – 15	0.0015	–	–	–	–
NO_x								
750 m	–	–	–	–	–	–	3.5 – 9.1	0.091
1,000 m	–	–	–	–	–	–	1.9 – 4.9	0.049
1,500 m	–	–	–	–	–	–	0.64 – 2.3	0.023
PM_{10}								
750 m	–	–	–	–	1.8 – 4.7	0.031	0.26 – 0.62	0.012
1,000 m	–	–	–	–	1.4 – 3.4	0.023	0.13 – 0.34	0.0068
1,500 m	–	–	–	–	0.83 – 2.3	0.015	0.063 – 0.16	0.0032

[a] Results for a generic wet setting bound the results for a generic dry setting.

[b] A hyphen (–) indicates that no standard is available for that averaging period.

[c] Ratio of the upper end of the concentration range divided by the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded.

H.3.4 Water and Soil

The methodology used to determine water and soil impacts is presented in Appendix C and Tomasko (1997).

The environmental resource needs for the manufacturing options are summarized in Table H.12. The resource requirements (in particular, the paved area, volume of excavated material, and water usage) would be greater for the uranium metal option than for the uranium oxide option. Because the manufacture and use option is based on a generic site without a specified location and description, impacts could not be assessed on a site-specific basis; however, the impacts to surface

TABLE H.12 Summary of Environmental Parameters for the Manufacture and Use Options

		Requirements	
Shielding Option	Unit	Construction	Operations[a]
Uranium oxide			
Land area	acres	90	–
Disturbed land	acres	54	–
Building area	acres	14	–
Paved area	acres	15	–
Pond area	acres	2.7	–
Excavated material	yd^3	175,000	–
Hauled material	yd^3	85,500	–
Annual water	million gal/yr	35	7.5
Wastewater	million gal/yr	7.9	4.8
Uranium metal			
Land area	acres	90	–
Disturbed land	acres	54	–
Building area	acres	15	–
Paved area	acres	18	–
Pond area	acres	2.7	–
Excavated material	yd^3	180,000	–
Hauled material	yd^3	88,000	–
Annual water	million gal/yr	43	7.4
Wastewater	million gal/yr	8.5	5.0

[a] A hyphen (–) indicates no environmental resource needs.

water, groundwater, and soil would be smaller for the uranium oxide option because of its smaller resource requirements.

If the manufacture and use facility were located on a site having an area that was large compared with the size of the facility, and if the facility was near a river having a minimum flow that was large compared with annual water use and wastewater discharge, impacts to surface water, groundwater, and soil would be negligible. Negligible impacts would occur because a large site and large river could provide sufficient resource buffering to mitigate the effects produced by construction and operation of the facility.

On the other hand, if the site or the minimum flow in the river were small relative to the resource requirements, impacts would be larger. For example, if the minimum flow in the river was 500 gpm, the net annual water withdrawal would be about 15% of the flow. The impact of this relative withdrawal could produce moderate to large impacts to existing floodplains.

Similarly, if the facility was located in an urban area, paving 18 acres (7 ha) and constructing buildings on another 15 acres (6 ha) could seriously impact the local carrying capacity of storm-water runoff and produce local flooding. In addition, the paving and construction of the facility on a 90-acre (36-ha) site would produce moderate to large impacts to local soil permeability and erosion potential.

No process water effluents would be anticipated from the manufacturing facility (LLNL 1997), so no impacts to surface water quality would be expected. There are no accidents identified in the engineering analysis report (LLNL 1997) that would directly impact surface water. Secondary impacts resulting from deposition of airborne contaminants would not be measurable because of the low concentrations of deposited material.

H.3.5 Socioeconomics

Because the location of a shielding manufacturing facility has not yet been determined, the socioeconomic impacts of the shielding manufacturing options were analyzed on a non-site-specific basis for a generic site. The potential impacts of each facility on direct employment and direct income in the peak year of construction and in first year of operations are shown in Table H.13. Discussion of the assessment methodology is presented in Appendix C and Allison and Folga (1997).

Construction of a UO_2 shielding manufacturing facility would create 160 direct jobs and \$7 million in direct income during the peak year of construction. Operation of the facility would create 470 direct jobs and produce \$33 million in direct income in each year of facility operations.

TABLE H.13 Potential Socioeconomic Impacts from Construction and Operation of the Shielding Manufacturing Facilities

Option/Parameter	Construction[a]	Operations[b]
Manufacture from UO_2		
Direct employment	160	470
Direct income ($ million 1996)	7	33
Manufacture from metal		
Direct employment	190	470
Direct income ($ million 1996)	9	33

[a] Impacts during the peak year of construction, 2007. Preoperations were assumed to occur from 1999 through 2008, with actual construction requiring 7 years.

[b] Impacts are the annual averages for operations for the period 2009 through 2028.

Construction of a metal shielding manufacturing facility would create 190 direct jobs and $9 million in direct income during the peak year of construction. Operation of the facility would create 470 direct jobs and produce $33 million in direct income in each year of facility operations.

H.3.6 Ecology

Moderate adverse impacts to ecological resources could result from construction of a shielding manufacturing facility. Impacts could include mortality of individual organisms, habitat loss, or changes in biotic communities. Impacts due to facility operation would be negligible. Discussion of the methodology used to assess ecological impacts is presented in Appendix C.

H.3.6.1 Uranium Oxide

Site preparation for the construction of a uranium oxide shielding manufacturing facility would require the disturbance of approximately 54 acres (22 ha), including the permanent replacement of approximately 32 acres (13 ha) with structures, paved areas, and a storm-water pond. Existing vegetation would be destroyed during land-clearing activities. The facility would be included within a 90-acre (36-ha) area consisting of buildings, roads, and landscaped areas, which would be maintained as a controlled access area. The specific vegetation communities that would be eliminated by site preparation would depend on the location selected for the facility. The loss of 54 acres (22 ha) of undeveloped land and limited vegetation community development on the remainder of the 90-acre site would constitute a moderate adverse impact to vegetation. Erosion of exposed soil at construction sites could reduce the effectiveness of restoration efforts and create sedimentation downgradient of the site. The implementation of standard erosion control measures, installation of storm-water retention ponds, and immediate replanting of disturbed areas with native species would help minimize impacts to vegetation. Impacts from facility construction are summarized in Table H.14.

Wildlife would be disturbed by land clearing, noise, and human presence. Wildlife with restricted mobility, such as burrowing species or juveniles of nesting species, would be destroyed during land clearing activities. Mobile individuals would relocate to adjacent available areas with suitable habitat. Population densities, and thus competition for food and nesting sites, would increase in these areas, potentially reducing the survivability or reproductive capacity of displaced individuals. Some wildlife species would be expected to recolonize replanted areas near the manufacturing facility following completion of construction. The permanent loss of 32 to 90 acres (13 to 36 ha) of habitat due to the construction of a facility for manufacture of uranium oxide shielding would be considered a moderate adverse impact to wildlife.

Wetlands could potentially be eliminated or otherwise impacted during construction. Impacts to wetlands and aquatic habitats due to alteration of surface water runoff patterns, soil compaction, or groundwater flow could occur. Unavoidable impacts to wetlands would require a

TABLE H.14 Impacts to Ecological Resources from Construction of the Manufacturing Facility

Option/Resource	Type of Impact	Degree of Impact
Uranium oxide		
Vegetation	Loss of 54 acres	Moderate adverse impact
Wildlife	Loss of 32 to 90 acres	Moderate adverse impact
Wetlands	Potential loss, degradation	Potential adverse impact
Aquatic species	Water quality, habitat reduction	Potential adverse impact
Protected species	Potential destruction, habitat loss	Potential adverse impact
Uranium metal		
Vegetation	Loss of 54 acres	Moderate adverse impact
Wildlife	Loss of 36 to 90 acres	Moderate adverse impact
Wetlands	Potential loss, degradation	Potential adverse impact
Aquatic species	Water quality, habitat reduction	Potential adverse impact
Protected species	Potential destruction, habitat loss	Potential adverse impact

Clean Water Act Section 404 permit, which might stipulate mitigative measures. Additional permitting might be required by state agencies.

Prior to construction of a manufacturing facility, a survey for state and federally listed threatened, endangered, or candidate species, or species of special concern would be conducted. Impacts to these species could thus be avoided, or, where impacts were unavoidable, mitigation could be developed.

Ecological resources in the vicinity of the manufacturing facility would be exposed to atmospheric emissions from the boiler stack and process stack; however, emission levels would be expected to be extremely low (Section H.3.3). The maximum annual air concentration of UO_2 would be approximately 1.6×10^{-7} $\mu g/m^3$. Consequent impacts to biota would be expected to be negligible.

The manufacturing process would require withdrawal of water from surface waters or groundwater, as well as discharge of wastewater. Depending on the facility location, such withdrawal and discharge could potentially alter water levels (Section H.3.4). The altered water levels could, in turn, impact aquatic ecosystems, including wetlands, especially those located along the periphery of the affected surface water bodies.

Facility accidents, as discussed in Section H.3.2, could result in adverse impacts to ecological resources. The affected species and degree of impact would depend on a number of factors, such as location of the accident, season, and meteorological conditions.

H.3.6.2 Uranium Metal

The construction of a facility for the manufacture of depleted uranium metal shielding would generally result in the types of impacts associated with the manufacture of uranium oxide shielding. However, site preparation for the construction of a metal shielding manufacturing facility would require the disturbance of approximately 54 acres (22 ha), including the permanent replacement of approximately 36 acres (15 ha) of current land cover with structures, paved areas, and a storm-water pond. The facility would be included within a 90-acre (36-ha) area consisting of buildings, roads, and landscaped areas, which would be maintained as a controlled access area. The loss of 54 acres (22 ha) of undeveloped land and limited vegetation community development on the remainder of the 90-acre (36-ha) site would constitute a moderate adverse impact to vegetation.

The permanent loss of 36 to 90 acres (15 to 36 ha) of habitat would be considered a moderate adverse impact to wildlife. Impacts to ecological resources from operation of the uranium metal manufacturing facility would be similar to those due to operation of the uranium oxide facility.

H.3.7 Waste Management

For both options, the construction and operation of a depleted uranium shielding manufacture facility would generate LLW, hazardous waste, and nonhazardous waste. The LLW would consist of surface contaminated metals; noncombustible, noncompactible solids; dry active wastes; spent high-efficiency particulate air (HEPA) filters; and incinerator ash. Hazardous wastes generated would include paints, thinners, solvents, phenol, mercury (lamps), sulfuric acid, naphtha, lead (batteries), and pesticides.

Because the uranium oxide or uranium metal facility was assumed to be constructed at a generic, uncontaminated site, no radioactive waste would be generated during construction. About 94 and 105 yd^3 (72 and 80 m^3) of hazardous waste would be generated during construction for the uranium oxide and metal shielding facilities, respectively. These wastes would be sent to existing commercial treatment and disposal facilities. Nonhazardous waste generated during construction would be expected to total about 78,000 and 92,000 yd^3 (60,000 and 70,000 m^3), respectively, for the two options.

All radioactive wastes generated during operation of the uranium oxide or uranium metal facility would be routed to the facility waste management station. This part of the facility would include a grouting station and an incinerator. Failed mixers from a uranium oxide facility would be sent directly to disposal; all other facility wastes would be grouted. Spent HEPA filters would be drummed for disposal, and dry active waste would be incinerated, with the resulting ash grouted for disposal. Table H.15 lists expected LLW generation. The annual generation of 165 and 850 yd^3 (126 and 650 m^3) of LLW requiring disposal represents about 600 and 3,200 drums, respectively, per year and would represent about 0.2 and 1% of the projected annual LLW treatment volume for all DOE facilities nationwide (see Appendix C, Section C.10). All of the radioactive waste would be categorized as Class A by the NRC and would be suitable for near-surface disposal. Unlike the uranium oxide option, solidified ash waste from the uranium metal facility might require disposal in a special cell or mine. Hazardous wastes generated during operations are expected to be about 4 times the volume generated during construction. About 275 to 330 tons (250 to 300 metric tons) of nonhazardous waste would be generated annually and would be sent to commercial landfills.

No assumptions were made regarding the fate of the oxide- and metal-shielded casks after use. The empty casks could be recycled, stored, or disposed of as LLW.

TABLE H.15 Summary of Waste Volumes from the Manufacture of Depleted Uranium Shielding

		Waste Volume	
Waste Type	Unit	Uranium Oxide	Uranium Metal
Construction[a]			
Hazardous	m^3	71.6	79.5
Nonhazardous	m^3	60,000	70,000
Operations[b]			
Low-level waste	m^3/yr	126	650
Hazardous	m^3/yr	286	318
Nonhazardous	metric tons/yr	250	300

[a] Total volumes generated during the entire 7-year construction period.

[b] Annual volumes generated over normal operating lifetime of 20 years.

H.3.8 Resource Requirements

Resource requirements for the two manufacture and use options are presented in this section. These resource requirements are for the manufacturing of depleted uranium shielding only and do not include resources required for conversion to uranium oxide or uranium metal. Resource requirements for conversion are presented in Appendix F, Section F.3.8.

Estimated utilities and materials required for constructing a shielding manufacturing facility are listed in Table H.16 for the uranium oxide and uranium metal options (LLNL 1997). These required materials and chemicals are readily available and are not considered rare or unique. The total quantities of commonly used construction materials is not expected to be significant. No strategic and critical materials (e.g., Monel or Inconel) are projected to be consumed during construction. Energy resources used during construction would include diesel fuel and gasoline for construction equipment and transportation vehicles. The required electricity would presumably be purchased from commercial utilities.

Energy resources required for operating the two types of shielding manufacturing facilities are shown in Table H.17. No strategic and critical materials (e.g., Monel or Inconel) are projected to be consumed for either construction or operations phases. Energy resources during operations would include the consumption of diesel fuel for operations equipment (including backup electrical generators) and natural gas for space heating. Small amounts of diesel fuel and natural gas are

TABLE H.16 Resource Requirements for Construction of Shielding Manufacturing Facilities

		Requirements	
Utility/Resource	Unit	Uranium Oxide	Uranium Metal
Utilities			
Electricity	MW-yr	4.7	4.9
Solids			
Concrete	yd^3	60,000	62,000
Steel	tons	11,600	12,000
Liquids			
Diesel fuel	million gal	0.61	0.63
Gasoline	million gal	0.2	0.2

Source: LLNL (1997).

TABLE H.17 Resource Requirements for Operation of Shielding Manufacturing Facilities

		Annual Requirement	
Resource	Unit	Uranium Oxide	Uranium Metal
Electricity	MW	3.8	4.7
Diesel fuel	gal	2,000	2,000
Natural gas	million scf	20	32

Source: LLNL (1997).

projected to be used. The required electricity would presumably be purchased from commercial utilities.

H.3.9 Land Use

The assessment of potential land-use impacts for the manufacturing and use options was based on a determination of areal requirements for each option and the potential for incompatibility. The uranium oxide and uranium metal options would result in similar moderate land-use impacts. Both facilities would have a total site requirement of 90 acres (36 ha), of which 54 acres (22 ha) would be disturbed or cleared (LLNL 1997). Although the uranium oxide facility would produce a slightly smaller volume of excavated material than the uranium metal facility, topographical modifications of on-site land could result under both options.

No site has been chosen for a uranium oxide or uranium metal facility, but selection of a site at or near a location that is already dedicated to or zoned for similar use could result in reduced land-use impacts because immediate access to infrastructure and utility support would be possible with only minor disturbances to existing land. Traffic patterns could experience potentially moderate level-of-service impacts from the peak year construction labor force. Any such traffic impacts, however, would be greatly reduced once post-construction operations begin.

H.3.10 Other Impacts Considered But Not Analyzed in Detail

Other impacts that could potentially occur if the manufacture and use options considered in this PEIS were implemented include impacts to cultural resources and environmental justice, as well as the visual environment (e.g., aesthetics), recreational resources, and noise levels, and impacts associated with decontamination and decommissioning of the manufacturing facilities. These impacts, although considered, were not analyzed in detail for one or more of the following reasons:

- The impacts could not be determined at the programmatic level without consideration of specific sites. These impacts would be more appropriately addressed in the second-tier *National Environmental Policy Act (*NEPA) documentation when specific sites are considered;

- Consideration of these impacts would not contribute to differentiation among the alternatives and, therefore, would not affect the decisions to be made in the Record of Decision to be issued following publication of this PEIS.

H.4 REFERENCES FOR APPENDIX H

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