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Sec 6

***Table C.4–9. Nonattainment Status Definitions[a]***

| Criteria Pollutant | Nonattainment Designation | NAAQS Exceedance Range |
|---|---|---|
| Carbon monoxide (CO) | Moderate-1 | 9.1 to 12.7 ppm |
| | Moderate-2 | 12.8 to 16.4 ppm |
| Ozone ($O_3$) | Marginal | 0.121 to 0.138 ppm |
| | Moderate | 0.138 to 0.160 ppm |
| | Severe-17 | 0.190 to 0.280 ppm |
| Particulate matter ($PM_{10}$) | Moderate | Greater than NAAQS |

[a] Only the nonattainment status designations used in Table C.4–8 are shown.

areas which are listed as in attainment of the NAAQS for each of the criteria pollutants. These allowable increases are referred to in the PSD regulations as PSD increments and PSD significant emission levels (SELs). If the estimated annual emissions exceeded the allowable PSD SELs increments, then that WM alternative and the affected area were noted in the PEIS. The air analysis only compared annual emissions to PSD SELs to determine whether a site could exceed the SELs and an action at a particular site could trigger a PSD review. The analysis should not be interpreted as being a refined PSD analysis. A refined PSD analysis would need to be performed prior to installation of any action at a potential PSD site. PSD increases account for all stationary-source emissions that can be reasonably attributed to the action but do not account for emissions from mobile sources. PSD increases for attainment areas are listed in Table C.4–10.

#### C.4.2.1.3.1.2 Impacts for Installations in Nonattainment Regions

New stationary sources or major modifications of existing sources located in *nonattainment* areas for criteria pollutants must conform to New Source Performance Standards for new, or modified, existing pollutant sources. In addition, Federal actions which are located in nonattainment areas are required to follow the GCR guidelines (40 CFR 93) in determining the conformity of the action to Section 176(c) of the CAA and to approved State or Federal implementation plans. The GCR establishes specified *de minimis* levels for criteria pollutant emissions, in tons per year, based on the AQCR's nonattainment designation. Actions producing emissions which are below the *de minimis* levels are considered to conform, while those equal to or above the limits are required to perform a conformity determination as outlined in the GCR. The GCR

***Table C.4–10. PSD Increments for Criteria Pollutant Emissions in Attainment Areas***

| Pollutant | Tons/Year |
|---|---|
| Carbon monoxide (CO) | 100 |
| Nitrogen dioxide ($NO_2$) | 40 |
| Ozone (as VOC) | 40 |
| Lead (Pb) | 0.6 |
| Particulate matter | 25 |
| Particulate ($PM_{10}$) | 15 |
| Sulfur dioxide ($SO_2$) | 40 |

Source: 40 CFR 52.21.

accounts for all stationary-sources and mobile sources of emissions that can be reasonably attributed to the action. GCR limits for criteria pollutants in nonattainment areas are listed in Table C.4–11.

### C.4.2.1.3.2 Impacts Evaluation for Hazardous (Including Radionuclides) and Toxic Air Pollutants

The determination of applicable emissions limits and allowable ambient concentrations for pollutants other than the six criteria pollutants, was performed on a site-by-site basis. This approach was necessary because site-specific information on existing levels of noncriteria contaminants was not readily available from the site or regulatory agencies. Information on ambient concentrations of such substances from DOE site monitoring and environmental impact statements was used when available and applicable. In addition, the applicable regulations and standards vary considerably from state to state. Detailed procedures were defined on a site-by-site basis and described in the pertinent site air quality analyses section in the PEIS waste-type chapters.

***Table C.4–11. General Conformity Rule de minimis Levels for Nonattainment Areas***

| Pollutant and Nonattainment Designation | *de minimis* Level (tons/year) |
|---|---|
| Ozone (Volatile Organic Compounds or Nitrogen Oxides): | |
| - Serious Nonattainment Areas | 50 |
| - Severe Nonattainment Areas | 25 |
| - Extreme | 10 |
| - Other ozone Nonattainment Areas (outside an ozone transport region) | 100 |
| - Marginal and moderate Nonattainment Areas (inside an ozone transport region) | |
| VOC | 50 |
| $NO_x$ | 100 |
| Carbon Monoxide (CO): | |
| - All Nonattainment Areas | 100 |
| Sulfur Dioxide ($SO_2$) or Nitrogen Dioxide ($NO_2$): | |
| - All Nonattainment Areas | 100 |
| Particulate Matter <10 microns ($PM_{10}$): | |
| - Moderate Nonattainment Areas | 100 |
| - Serious Nonattainment Areas | 70 |
| Lead (Pb): | |
| - All Nonattainment Areas | 25 |

Source: 40 CFR 51.

### C.4.2.1.3.3 Impacts Evaluation for Ozone Precursor Emissions

Ozone pollution is generally caused by reactions between VOC and $NO_x$, in the presence of sunlight, and generally reaches its maximum many miles downwind of the sources of these substances. The impacts of the WM alternatives on ambient ozone levels were assessed by comparing changes in emissions of VOC and $NO_x$ with the total rate of emissions of these substances from the DOE site, the county, or the AQCR in which the emissions occur. It was assumed that changes in ozone precursor emissions would result in corresponding changes in downwind ozone levels.

#### C.4.2.1.3.4 Ozone Depleting Substances

The stratospheric ozone layer protects the earth from the penetration of harmful ultraviolet radiation. On the basis of substantial scientific evidence, a national and international consensus currently exists that certain man-made halocarbons (including CFCs, halons, carbon tetrachloride, and methyl chloroform), react in the upper atmosphere to deplete the stratospheric ozone layer.

In response to this awareness, the United States and 22 other countries in 1987 signed the Montreal Protocol on Substances that Deplete the Ozone Layer. The Montreal Protocol, as originally drafted, called for a freeze on the production of CFCs at 1986 levels and for CFCs to be reduced by 50% by 1998.

The CAA, as amended, includes requirements for controlling ozone depleting substances that are generally consistent with, but in some cases, more stringent than those contained in the Montreal Protocol. Title VI of the CAA, and the implementing regulations (40 CFR 82), call for a phaseout of CFCs by January 1, 2000. In addition to the phaseout of ODS, Title VI includes a variety of other provisions intended to reduce emissions of ODS and promote the recycling of these substances. In addition, DOE facilities are required to adhere to Executive Order 12843 of April 23, 1993: *Procurement Requirements and Policies for Federal Agencies for Ozone-Depleting Substances*. This Executive Order stipulates that all Federal Agencies must implement cost-effective programs to minimize the procurement of materials and substances that contribute to the depletion of stratospheric ozone; and give preference to the procurement of alternative chemicals, products, and manufacturing processes that reduce overall risks to human health and the environment by reducing the depletion of ozone in the upper atmosphere.

Impacts to the stratospheric ozone layer due to emissions from WM activities were estimated. The analysis was performed at the alternative level since emissions of ozone depleting substances is a global rather than a site issue. The analysis was performed for waste types where treatment of waste containing hazardous constituents occurs (i.e., LLMW, TRUW and HW). The compounds analyzed include the ozone depleting substances identified by EPA in 40 CFR 82. Emissions of ozone depleting substances from incineration were tallied from information supplied by the health risk assessment. The total emissions from each alternative were found to be exceedingly small for all waste types, and in fact were $<0.1$ pound per year for all LLMW alternatives (DOE, 1996a). These minor emissions would not be expected to have any measurable affect on upper atmosphere ozone levels. Emissions of ozone depleting substances from other

treatment, storage and disposal operations were assumed to be small due to the nature of these activities, and the mandated phase-out of the use of ozone depleting substances.

## C.4.3 WATER RESOURCES IMPACTS ANALYSIS METHODS

This section describes the methods used to estimate the impacts of proposed WM alternatives on surface water and groundwater resources. Section C.4.3.1 provides an introduction, C.4.3.2 briefly describes the regulations that limit impacts to water resources, C.4.3.3 lists the assumptions used in the impacts analyses, C.4.3.4 describes impacts that were considered but not evaluated in detail, and C.4.3.5 describes the methods used to assess the impacts on water resources that were evaluated in detail.

### C.4.3.1 Introduction

The alternatives analyzed in this PEIS can affect the quantity or the quality of surface water and groundwater. Water availability elements that may be affected include surface water flow, floodplains, groundwater flow, and aquifer water levels. Surface water and groundwater rights, allocations and usage may also be affected. Water quality elements that may be affected include areas of surface water and groundwater that are already contaminated, and receiving water bodies such as streams, lakes, rivers, and groundwater aquifers. The ROI for water resources is the area encompassed by onsite and offsite surface water and groundwater bodies and their watersheds, which may be affected by site activities.

Water availability is affected when water withdrawal or discharge causes an appreciable change in surface water flow or groundwater levels. Water quality is affected when discharges cause an appreciable increase in the concentration of sediments or contaminants in the receiving water body. In addition, water quality may be affected when activities cause the movement of existing contamination. For example, activities that change the water table gradient could accelerate offsite movement of a plume of groundwater contamination.

Construction, operation, and transportation activities can adversely affect water resources, both during normal operations and when an accident occurs. Waste management activities may adversely affect surface and groundwaters, as a result of increased water use, increased stormwater runoff, increased wastewater discharges, and releases to groundwater from disposal facilities. Transportation of wastes may affect water

resources from the deposition of exhausts emitted from the vehicles and from accidental spills into water bodies.

### C.4.3.2 Regulatory Considerations

The Clean Water Act (33 USC 1251 *et seq.*), as amended, requires a permit for all discharges to surface waters (including stormwater discharges) under the National Pollutant Discharge Elimination System (NPDES) program. NPDES permits set discharge limits for contaminants and require periodic monitoring to ensure compliance. In addition, Section 404 of the Clean Water Act regulates the discharge of fill material into navigable waters of the United States.

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 USC 9601 *et seq.*), as amended, requires the cleanup of contaminated areas and specifies cleanup levels by application of Applicable or Relevant and Appropriate Requirements (ARARs).

The Safe Drinking Water Act (42 USC 300 *et seq.*) regulates drinking water quality. The maximum contaminant levels established in the implementing regulations (40 CFR 141), although not directly applicable to groundwater quality, are commonly used as ARARs to determine appropriate levels for groundwater cleanup. Since the drinking water standards adequately protect human heath, concentrations of contaminants in groundwater at or below these levels present a low risk. In addition, DOE derived concentration guides for drinking water (DOE, 1990) are sometimes cited as "to be considered" requirements under CERCLA.

Executive Order 11988 (Floodplain Management) and 10 CFR 1022 (Compliance with Floodplain/Wetland Environmental Review Requirements) require that proposed projects be reviewed to determine their impact on floodplain and wetland areas. Federal agencies are required to avoid, when possible, occupying and modifying floodplains. Floodplain and wetland assessments are required for actions that occur within the 100-year floodplain, and for "critical actions" that occur within 500-year floodplains.

Monitoring of effluents and nearby water bodies for adverse effects from WM facilities is required by a number of statutes and their related regulations. Under the Clean Water Act, the NPDES requires that discharges to waters of the United States be monitored and that levels of contaminants in the effluent remain

below permitted levels. The Clean Water Act, as amended, also requires stormwater discharges to be monitored. The regulations implementing the RCRA (42 USC 6901 *et seq.*) have extensive requirements for groundwater monitoring at hazardous waste treatment, storage, and disposal facilities. Levels of contaminants in the groundwater must remain below levels described in the regulations. The regulations of the Toxic Substances Control Act (15 USC 2601 *et seq.*) require similar monitoring at treatment, storage, and disposal facilities for asbestos and polychlorinated biphenyls (PCBs). DOE orders (e.g., 5820.2A [DOE, 1988]), require surface water and groundwater monitoring at radioactive waste treatment, storage, and disposal facilities. In addition, EPA regulations (40 CFR 191) require monitoring of treatment, storage, and disposal facilities at DOE sites that dispose of HLW and TRUW.

Monitoring generally involves periodic measurement of characteristics of the effluent or receiving water body including measurement of radionuclide and chemical concentrations, temperature, pH, and flow. Groundwater monitoring usually involves the analysis of samples collected from wells drilled for this purpose. Surface water monitoring generally involves sampling from stations located downstream from the effluent discharge point. These monitoring stations are located such that they are likely to intercept any releases from a WM facility.

Monitoring provides the opportunity to detect excessive discharges from a WM facility before significant harm is done to human health or the environment. Once the cause of the excessive discharge is located, corrective actions are implemented to contain and then eliminate the source of the problem. DOE will comply with all applicable monitoring requirements.

### C.4.3.3 Assumptions

Assumptions for the water resources impacts analysis included the following:

- Current conditions of water resources adequately represent future baseline conditions.
- Water for WM activities would be supplied by current water sources. If water is currently supplied by wells in aquifer X, water for the proposed alternatives would be supplied by wells in aquifer X. If water is currently supplied by a municipal system, then water for the proposed alternatives would be supplied by that system. If water is currently supplied by river Y, water for new facilities would be supplied by river Y.

- Because municipal water is used as the current source, onsite surface water and groundwater resources would not be affected by water withdrawals at Rocky Flats Environmental Technology Site (RFETS), Sandia National Laboratories-New Mexico (SNL/NM), and Waste Isolation Pilot Plant (WIPP). Because groundwater is used as the current source, impacts to surface water resources are likely to be small as a result of groundwater withdrawals at Argonne National Laboratory-East (ANL-E), Brookhaven National Laboratory (BNL), Fernald Environmental Management Project (FEMP), INEL, Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL) Site-300, Nevada Test Site (NTS), Pantex Plant, Portsmouth Gaseous Diffusion Plant (PORTS), and SRS. Because surface water is the current source, impacts to groundwater resources are likely to be small as a result of surface water withdrawals at Hanford, Oak Ridge Reservation (ORR), Paducah Gaseous Diffusion Plant (PGDP), and WVDP.
- Although some sites under consideration receive water from more than one source, they are assumed to obtain their water as follows: (1) Hanford Site from surface water; and (2) LLNL Site-300 and SRS from groundwater. Since only a small portion of the Hanford Site is supplied by groundwater, it was assumed that all water would be supplied by surface water. At LLNL Site-300, water is supplied by an offsite municipal source and onsite groundwater, but to be conservative, it was assumed that groundwater supplied all the water to the site. At SRS, surface water is generally used only for cooling water. Therefore, it was assumed that groundwater would be used to supply WM facilities.
- During normal operations, no untreated sanitary or process wastewater would be discharged to surface or groundwaters at any site. Wastewater would be recycled to the extent possible and then discharged to existing process or sanitary treatment plants, as appropriate. After treatment, wastewater would be discharged from these plants in compliance with all NPDES and industrial wastewater discharge permits.
- Sanitary wastewater treatment capability was not included among the new WM facilities to be constructed. Therefore, it was assumed that sanitary wastes would be discharged to existing plants. New capability to treat process wastewater was included for WM facilities to be constructed.
- The manner of disposing wastewater would not change. If wastewater is currently discharged to a municipal sewer system, than future wastewater would be discharged to that system. If wastewater is currently discharged to a treatment plant, effluent would continue to be discharged to the treatment plant.
- Since the locations for the WM have not been selected, it was not possible to determine which particular onsite water course(s) would be affected. For this impacts assessment, the major offsite water body was assumed to be the receiving water body.

- Onsite surface water resources would not be affected by effluent discharges at SNL/NM, because wastewaters are discharged to municipal wastewater treatment systems. Surface water resources would not be affected by effluent discharges at Hanford, INEL, LANL, LLNL Site-300, NTS, Pantex, or WIPP, because generally, wastewaters are discharged to dry stream beds or man-made ponds, and not to natural-flowing surface water bodies.
- For municipal water supply systems, withdrawals up to the capacity of the site distribution system are acceptable. It was assumed that, if water is available from the utility, the necessary steps have been taken to ensure that operations meet Federal, State, and local environmental regulations. These steps may include withdrawal permits, water rights agreements, and environmental impact reports. This same assumption applies to municipal wastewater treatment.
- During normal operation of waste storage facilities, no water (including precipitation, surface water, or groundwater) would be allowed to come into contact with the waste. Therefore, surface and groundwater quality would not be affected because runoff would not be contaminated. During normal operation of waste treatment facilities, no releases directly to groundwater would occur. Therefore, groundwater quality is not likely to be affected.
- Seepage of contaminated groundwater from disposal facilities could contaminate surface water. This contamination would be diluted by surface water flows such that the concentration in the surface water would be less than the concentration in the groundwater.
- As described in Appendix E, for waste transported in U.S. Nuclear Regulatory Commission (NRC) Type B certified containers, the probability of container leakage during an accident would be very low. Therefore, transportation accidents involving Type B containers were assumed not to affect surface or groundwater resources.

### C.4.3.4 Impacts Considered but Not Evaluated in Detail

This section describes potential impacts to water resources that were not evaluated in detail in the PEIS. These impacts were not evaluated in detail because they (1) could be evaluated generically rather than for each alternative; (2) are believed to be minor; or (3) require site-specific analyses that are not possible at this time.

### C.4.3.4.1 *Impacts to Floodplains*

If possible, new WM facilities would be located outside the 100-year floodplain, and if the facilities are considered "critical actions," would be located outside the 500-year floodplain. As a minimum, facilities managing LLMW or HW would be required to meet additional design criteria and/or siting requirements to obtain an RCRA permit. Even if the WM facilities are located outside floodplains, access roadways and utility corridors may encroach on floodplains. The impacts of these activities cannot be estimated at this time since the specific locations of the WM facilities have not been selected. Compliance with floodplain and wetland review requirements, including Executive Order 11988 (Floodplain Management) and 10 CFR 1022 (Compliance with Floodplain/Wetland Environmental Review Requirements), would be examined in detail when specific locations are proposed during sitewide or project-specific NEPA reviews.

### C.4.3.4.2 *Impacts From Runoff and Sedimentation*

During the construction period, surface water resources could be affected by runoff and sedimentation from site clearing. During operations, water resources could be affected by increased runoff from buildings, parking lots, and cleared areas. Generally, the impacts would be proportional to the amount of land disturbed during construction or occupied during operations. In all cases, the effects would be minimized by implementing the best management practices for stormwater runoff and erosion control. These practices include the use of silt fences, runon and runoff diversion ditches, and stormwater retention and sedimentation ponds. In addition, stormwater discharges would be regulated by the new NPDES stormwater discharge permits. Therefore, impacts from these activities are not expected to be major, and should not influence the choice of alternatives. If necessary, these impacts would be evaluated in sitewide or project-specific NEPA documents.

During WM operations, stormwater runoff may be contaminated with small quantities of materials deposited from air-borne emissions. Some of the potentially contaminated stormwater runoff would be contained within onsite stormwater collection ponds. The stormwater runoff would evaporate or infiltrate into the ground, although the ponds may discharge to surface water bodies during high flow conditions. The volume of stormwater in the ponds would be expected to change somewhat between the alternatives, depending on the size of the areas drained, but the quality of the water would be expected to be similar. Stormwater runoff would be routinely monitored and any discharges would be in compliance with site-specific permit

limits. The impacts of runoff were not evaluated in quantitative fashion but were assumed to be low due to regulations and practices for erosion control and stormwater management. Impacts from stormwater runoff are highly site-specific and would be considered in NEPA documents tiered to the WM PEIS.

Stormwater runoff that is not contained within the stormwater management system may contaminate surface waters. This runoff may contain small amounts of contamination from airborne emissions. Controls would be implemented at each site to minimize the potential for contaminated stormwater runoff. Impacts from contaminated stormwater runoff are expected to be minor, but are highly site-specific and would depend on the design of the stormwater management system, meteorologic conditions, topography, soil, and the affected surface water body at the site. These impacts should not influence the choice of alternatives, but would be considered in sitewide or project-specific NEPA documents if necessary.

### C.4.3.4.3 *Impacts From Sanitary Wastewater Discharges*

The majority of any new aqueous waste would be sanitary waste generated by the employees needed for the alternative. Sanitary wastes by definition are nonhazardous and would be discharged to existing sanitary wastewater treatment facilities. After treatment, sanitary wastewaters would be recycled, or discharged from these plants in compliance with site-specific NPDES, or industrial wastewater discharge permit limits. Limits on the amount of contaminants in the effluent are set by the regulators after consideration of potential adverse ecological and human health effects in the receiving water body. The impacts on existing sanitary wastewater treatment facilities are discussed in the infrastructure sections of each waste-type chapter.

Although the volume of sanitary wastewater may vary between alternatives, it would remain similar in quality. Therefore, current conditions would not change appreciably unless the discharge volume was a large percentage of the flow in the receiving water body. The impacts of combined sanitary and process wastewater discharges on surface water availability were evaluated for all waste types in the site tables, and show only minor (less than 1%) changes in flow. Since the quality of effluent discharges from sanitary wastewater treatment facilities would not change, and the flow would not be a significant fraction of the average flow in the major receiving water body, current monitoring captures the majority of the water quality effects of sanitary wastewater treatment plant discharges for the alternatives. Therefore, impacts from these activities are not expected to be major, and should not influence the choice of alternatives. If necessary, these impacts would be considered in sitewide or project-specific NEPA documents.

### C.4.3.4.4 *Impacts From Process Wastewater Discharges*

Process wastewater is wastewater potentially contaminated by hazardous or radioactive constituents during treatment, storage, or disposal activities. In the WM PEIS, it was assumed that easy-to-treat and hard-to-ship wastes, such as aqueous wastes and slurries (process wastewater), would be treated at the generating site and would not be shipped off site for treatment. After treatment, wastewaters would be recycled or discharged in compliance with site-specific DOE, NPDES, or industrial wastewater discharge limits. Because process wastewater treatment would continue at the sites where it presently occurs and because the volumes of process wastewater treated at each site would vary only slightly between alternatives, the effects of process wastewater treatment on surface water and groundwater quality are largely accounted for in the affected environment section. Therefore, the impacts from these activities should be similar for all alternatives and should not influence the choice of alternatives. If necessary, these impacts would be evaluated in sitewide or project-level NEPA documents.

### C.4.3.4.5 *Impacts to Small Onsite Streams*

Wastewater released by WM facilities may enter small onsite water courses before entering the major surface water body near the site. Additional effluents in these small streams, may cause eroding of parts of the stream channel and sedimentation in other parts of the channel. Water quality may also be affected because the facility effluents may form a large fraction of the natural streamflow. Before NPDES permits are renewed or issued by the EPA or state agencies, water quality in the receiving water body would be considered in setting effluent limits for the facilities. Impacts on small onsite water bodies would be considered in detail in sitewide or project-specific NEPA documents.

### C.4.3.4.6 *Impacts of Water Withdrawals on the Movement of Groundwater Contamination*

Withdrawals of groundwater for use by WM facilities could cause the movement of existing areas of groundwater contamination. This could occur where water levels are lowered by water withdrawals. Impacts of this sort are unlikely because existing wells would be used to the extent possible, and new wells would be located to minimize their impact on the movement of existing contaminant plumes. Impacts on

existing areas of contamination would be considered in detail in sitewide or project-specific NEPA documents.

### C.4.3.4.7 *Impacts From Waste Disposal on Surface Water Quality*

Seepage of contaminated groundwater from disposal facilities could contaminate surface water. This would be expected to occur at sites with shallow groundwater, and surface water bodies that are fed by groundwater discharge (springs). Some sites (INEL, NTS, and Pantex) are located above deep groundwater such that surface water would not be expected to become contaminated. Other sites (LANL, LLNL, SNL/NM, and WIPP) have a low potential for surface water contamination due to the intermittent nature of most of the sites streams. Where contaminated groundwater discharges to the surface, dilution in "clean" surface waters would cause concentrations of contaminants in surface water to be lower than concentrations in groundwater. Therefore the groundwater pathway was assumed to be the major pathway for movement of contaminants beyond the disposal facility boundary, and was the pathway that was examined in detail.

### C.4.3.4.8 *Impacts From Transportation*

Routine transportation would involve the intersite movement of waste by truck or rail, and the travel of workers to and from work. Waste materials would not be released during routine transportation of wastes. Therefore, impacts from transportation would be limited to the deposition and runoff of vehicle emissions to surface waters and the infiltration of materials deposited on the surface into groundwaters. As described in Section C.4.2 on air quality, vehicle emissions at any one place from transportation would be small. Therefore, the impacts of routine transportation on surface and ground waters would be minimal.

### C.4.3.4.9 *Impacts From Transportation Accidents*

Because the waste would be shipped in sealed NRC or DOT approved containers, impacts to water resources would be unlikely unless a ruptured container fell directly into a surface water body. In the unlikely event that waste was released from a shipping container, cleanup response to the accident would be swift, and the release would be contained and cleaned up as quickly as possible. The spill response and

cleanup, and any subsequent remediation, would be conducted in accordance with the CERCLA as amended, the National Oil and Hazardous Substances Pollution Contingency Plan, and DOE emergency response requirements. Since a swift cleanup would occur, long-term impacts to water quality are unlikely. Potential short-term impacts on water quality and on aquatic resources are addressed in Sections 7.7.5 and 8.7.5 of Volume I.

### C.4.3.4.10 *Vulnerability of Sites to Surface Water Impacts*

The primary water-related impacts of WM activities are likely to be through groundwater. Nevertheless, there may be sites at which WM activities could cause surface water impacts. This section provides a qualitative assessment of the vulnerability of sites to surface water impacts. The approach used here is to identify some of the key factors that could contribute to surface water impacts and identify those sites at which surface water may be an important pathway for movement of contaminants offsite. It is important to recognize that these sites are not pristine areas, but are already the source of some pollutants that potentially affect the surrounding surface water bodies.

Table C.4–12 provides information on:

- Average annual precipitation, which gives an indication of the likelihood for pollutants to be transported offsite through stormwater runoff
- The major surface water bodies near each site, their distance from the site, and their average flow rate, which indicates the relative importance of the surface water body and the likely impact on it of contaminants from the WM activities
- The presence of groundwater discharge to surface water bodies near the site, which indicates a mechanism other than direct discharge by which WM activities could impact surface water quality
- The presence of nearby surface water supply intakes downstream from the site, which indicates the potential exposure of human populations

Several of the sites are in arid to semiarid climates with limited rainfall and have no discharges to major surface water bodies (i.e., INEL, NTS, Pantex, and WIPP). Site wastewater discharges and stormwater runoff are unlikely to reach major surface water bodies, and little or no groundwater discharges into streambeds. These characteristics make it unlikely that WM activities would produce major surface water impacts near these sites.

*Table C.4–12. Key Factors Contributing to Surface Water Impacts*

| Site | Average Annual Precipitation (cm)[a] | Major Surface Water Bodies | | | Presence of Groundwater Discharge to Surface Water Onsite or near Site Boundary[b] | Presence of Nearby Drinking Water Supply Intakes Downstream from Site[b] |
|---|---|---|---|---|---|---|
| | | Major Surface Water Bodies Within 10 Miles of Sites[b] | Distance to Major Surface Water Bodies[b] | Average Flow Rate of Major Surface Water Bodies Near Sites (gpd)[b] | | |
| ANL-E | 80 | Des Plaines River | <1 mile | 582 million | Yes | No |
| BNL | 107 | Peconic River | Onsite | 1 million | Yes | No |
| FEMP | 104 | Great Miami River | <1 mile | 1.823 billion | Yes | No |
| Hanford | 16 | Columbia River | Onsite | 77.560 billion | Yes | Yes |
| INEL | 23 | None[c] | NA | NA | No | No |
| LANL | 47 | Rio Grande | At site boundary | 1.727 billion | Yes | No |
| LLNL-Livermore | 36 | None[c] | NA | NA | No | No |
| LLNL-Site 300 | 36 | None[c] | NA | NA | Yes | No |
| NTS | 19 | None[c] | NA | NA | No | No |
| ORR | 139 | Clinch River | At site boundary | 3.003 billion | Yes | Yes |
| PGDP | 120 | Ohio River | <2 miles | 174.521 billion | Yes | No |
| Pantex | 51 | Onsite playa basins that do not connect with offsite surface water bodies | NA | NA | No | No |
| PORTS | 101 | Scioto River | <1 mile | 3.036 billion | Yes | No |
| RFETS | 38 | Walnut Creek | Onsite | 142 million | Yes | Yes; but all onsite discharges are diverted around water supply |
| SNL-NM | 20 | Rio Grande | 6 miles from edge of Kirtland AFB | 651 million | Yes | No |
| SRS | 122 | Savannah River | At site boundary | 6.463 billion | Yes | No |
| WIPP | 31 | None[c] | NA | NA | No | No |
| WVDP | 104 | Buttermilk Creek | Onsite | 41 million | Yes | No |

Note: NA = not applicable.
[a] Data from DOE (1996a).
[b] Data from DOE (1995b).
[c] Stream channels are dry for most of the year.

At three other sites with arid to semiarid climates (LANL, LLNL, and SNL-NM), discharges off site occur uncommonly and are made up largely of stormwater runoff or snowmelt. At these sites, groundwater can seep into the beds of the intermittent streams at times during the year. These characteristics also make it unlikely that WM activities would cause major surface water impacts near these sites.

At RFETS, annual average precipitation is also low, although groundwater discharges into the nearby creeks. Parts of the site originally drained via small creeks to two reservoirs that are used for drinking water supplies by the towns of Broomfield and Westminster. Since 1989, all discharges from the RFETS are contained in onsite manmade ponds and diverted to the Broomfield Diversion Ditch, which bypasses the reservoirs and discharges to Walnut Creek downstream from the reservoirs. Although past activities at RFETS have impacted surface water resources, it is unlikely that major impacts to surface waters would occur from the incremental addition of WM activities.

ANL-E, FEMP, Hanford, ORR, PGDP, PORTS, and SRS are near major water bodies that have large to very large average flows. Groundwater at these sites recharges into the nearby streams and rivers. These characteristics indicate that although some impacts to surface water are likely to occur near these sites, it is unlikely that major surface water impacts would occur.

BNL and WVDP are near water bodies with small to medium average flows. During wet periods groundwater discharges to onsite streams. While these sites are more vulnerable to surface water contamination than are the sites discussed in the previous paragraphs, in the near term surface water impacts from the incremental addition of WM activities are not expected to be major. As described in the Draft WVDP closure EIS, significant impacts to surface water could occur in the future if erosion breaches the waste disposal facilities.

Most of the sites do not have downstream water supply intakes nearby, although there are nearby water supply intakes downstream from Hanford, ORR, and RFETS. At RFETS site discharges are routed around the water supply reservoirs and at Hanford and ORR the large surface water bodies provide a great deal of dilution of any contaminants released from the sites; therefore, major impacts to downstream drinking water supplies from WM activities at these sites are unlikely.

Impacts on surface water resources and drinking water supplies would be considered in sitewide or project-specific NEPA documentation, after the locations of WM facilities on the sites are selected.

### C.4.3.5 Impact Assessment Methods for Water Resources

The environmental impacts on surface water and groundwater availability and groundwater quality were assessed by determining the potential change from baseline conditions caused by implementing the Alternatives. A summary of the water resources impacts that were evaluated in detail in the PEIS is shown in Table C.4–13.

First, current conditions at the sites were summarized from data in the *Technical Report on Affected Environment* (DOE, 1995b). Table C.4–14 shows the affected environment information used for each site, which includes the following types of information:

- Source(s) of water for the site
- Current rate of municipal water use (gallons per day)
- Current rate of surface water use (gallons per day)
- Current rate of groundwater use (gallons per day)
- Location of wastewater discharge(s)
- Average streamflow for the major water body (gallons per day)
- The presence of Sole-Source Aquifers in the ROI as defined by the EPA
- The presence of Federally designated Wild and Scenic Rivers in the ROI

Then the applicable facility design data for the sites affected by the proposed alternatives were assembled from the data tables in this appendix, including:

- Water used during construction (total gallons)
- Water used during operations (gallons per year)

Water used during construction was converted to daily usage by dividing by the total number of days of the construction period, assuming 250 work days per year and a 2-year construction period. Water used during operations was converted to daily usage, assuming 250 work days per year. Figures for the number of work days per year for construction and operation and for the duration of the construction period were supplied in the EG&G reports (e.g., EG&G and MK, 1994).

*Table C.4–13. Impacts Evaluated in Detail for Water Resources*

| Impacts Assessed | Relevant Waste Types | Period of Analysis | Activities for Which Impacts Are Assessed | Impacts Measure | Presentation of Results |
|---|---|---|---|---|---|
| Water Availability | All five waste types | Construction | Estimated for water used:<br>- by personnel<br>- for concrete<br>- for dust suppression | Percent increase in current water use | Tabular and text discussion |
| | | | | Percent decrease in stream flow | Text discussion |
| | All five waste types | Operations | Estimated for water used:<br>- by personnel<br>- by treatment and disposal processes | Percent increase in current water use | Tabular and text discussion |
| | | | | Percent decrease in stream flow | Text discussion |
| | | | Estimated for effluent discharged from sanitary and process wastewater treatment facilities | Percent increase in stream flow | Text discussion |
| Groundwater Quality | LLMW and LLW | Post-Closure | Disposal of waste | Percent of drinking water quality standard | Tabular and text discussion |

The following calculations were performed for each alternative by combining the baseline environmental data with the facility design data:

- Percentage of current site water usage for increment added during construction
- Percentage of average streamflow for water usage increment added during construction
- Percentage of current site water usage for increment added during operations
- Percentage of average streamflow for water usage increment added during operations
- Percentage of average streamflow for effluent discharge increment added during operations, assuming that all water used is ultimately discharged as effluent from a wastewater treatment facility

These calculations formed the basis for assessing the impacts of the proposed alternatives on water availability.

## *Table C.4–14. Affected Environment Data for Water Resources*[a]

| Site | Source of Water Supply for Site | Current Use (gpd) | | | Waste-Water Discharge Location | Average Flow in Major Stream (gpd) |
|---|---|---|---|---|---|---|
| | | Municipal Water | Surface Water | Groundwater | | |
| ANL-E | Chicago Sanitary & Ship Canal and Niagara Aquifer | NA | 350,000 | 626,000 | County of DuPage Municipal Sewer System, Sawmill Creek | 582,000,000 |
| BNL | Upper Glacial Aquifer & Magothy Aquifer[b] | NA | NA | 4,500,000 | Onsite Streams & Peconic River | 1,000,000 |
| FEMP | Miami Valley Aquifer[b] | NA | NA | 400,000 | Onsite Streams & Great Miami River | 1,823,000,000 |
| Hanford | Columbia River, Deep Wells and City of Richland Municipal System | d | 9,567,000 | 184,000 | Onsite Drain Fields, Evaporation Ponds & Columbia River | 77,560,000,000 |
| INEL | Snake River Plain Aquifer[b] | NA | NA | 5,700,000 | Onsite Evaporation Ponds | NA |
| LANL | Main Aquifer | NA | NA | 4,100,000 | Onsite Canyons | 1,727,000,000 |
| LLNL Site-300 | Deep Groundwater & Hetch Hetchy Aqueduct | e | NA | 87,000 | Onsite Ponds and Leach Fields | NA |
| LLNL-L | Hetch Hetchy Aqueduct and Alameda County | 717,000 | NA | NA | City of Livermore Municipal Sewer System | NA |
| NTS | Groundwater | NA | NA | 1,367,000 | Onsite Evaporation Ponds | NA |
| ORR | Clinch River | NA | 18,300,000 | NA | Onsite Streams & Clinch River | 3,003,000,000 |
| PGDP | Ohio River | NA | 15,000,000 | NA | Onsite Streams & Ohio River | 174,521,000,000 |
| Pantex | Ogallala Aquifer | NA | NA | 548,000 | Onsite Playas | NA |
| PORTS | Alluvial Aquifer & Scioto River | NA | 0 | 14,000,000 | Onsite Streams & Scioto River | 3,036,000,000 |
| RFETS | Denver Water Board | 272,000 | NA | NA | Onsite Streams & Walnut Creek | 142,000,000 |
| SNL/NM | City of Albuquerque & Kirtland Air Force Base | 1,000,000 | NA | NA | City of Albuquerque WWTP | 651,000,000 |
| SRS | Groundwater & Savannah River | NA | 112,000,000 | 1,600,000 | Onsite Streams & Savannah River | 6,463,000,000 |
| WIPP | City of Carlsbad Municipal System | 14,400 | NA | NA | Onsite Evaporation Ponds | NA |
| WVDP[c] | Two Onsite Surface Water Reservoirs | NA | 70,000 | NA | Onsite Streams & Buttermilk Creek | 41,000,000 |

Notes: WWTP = waste water treatment plant. NA = not applicable. INEL includes INEL, ANL-W, and NRF. LLNL-L includes LLNL-L and SNL/CA. SNL/NM includes SNL/NM and ITRI.

[a] Data from the *Technical Report on Affected Environment for DOE Sites Considered in the Waste Management Programmatic Environmental Impact Statement* (DOE, 1995b). No Sites have Federally designated Wild and Scenic Rivers in the ROI, although the Hanford Reach of the Columbia River was recommended for inclusion (DOI, 1994).

[b] Sole-source aquifer.

[c] Site is upstream from a sole-source aquifer.

[d] Water use rate not available. Municipal water used to supply administrative areas (700, 1100, and 3000 Areas) near the City of Richland only.

[e] New system that has a capacity of 500,000 gallons/day.

Percentages less than or equal to 1% were considered to be negligible and were not discussed further. The 1% threshold is based on the assumption that a change in current conditions of this magnitude is not likely to produce a significant impact. Thus the 1% level was used as a screening level below which impacts were assumed to be minor.

Percentages greater than 1% were examined on a case-by-case basis because impacts would depend on the characteristics of the affected site. At one site a change in groundwater usage of 10% may be problematic, while at another site a change of this magnitude may not be a problem. When necessary, water usage was compared to the capacity of the water supply distribution system, regional water use, or water rights agreements to determine if these values would be exceeded. The effects of projected demands for proposed facilities on existing water supply or wastewater treatment infrastructures are evaluated in the section on infrastructure impacts.

The impacts of waste disposal on groundwater quality were estimated by using the information for the groundwater pathway generated during the health effects modeling. The movement of contaminants was modeled for each site using the Multimedia Environmental Pollutant Assessment System (MEPAS) code, modified to better account for radioactive decay and ingrowth of daughter radionuclides. The model estimated concentrations for radionuclides and hazardous constituents at a hypothetical well located 300 meters from the center of the disposal facility for 70-year increments between the end of institutional control and 10,000 years. Impacts from leakage during operations and institutional control are unlikely since leachate and groundwater monitoring are likely to detect the leak before significant degradation of groundwater quality could occur. Disposal of 36 radionuclides was evaluated for LLMW and LLW; disposal of 15 hazardous constituents was evaluated for LLMW. The maximum concentrations above 0.001 pCi/L for radionuclides and 0.000001 mg/L for hazardous constituents were then tabulated and compared to groundwater quality comparison criteria. The year of the maximum concentration was also included in the tabulation. Values above 25% of the comparison criteria were noted, and the potential impacts of these concentrations were discussed in the PEIS. Appendix D provides more detail on the health effects methodology used to model the groundwater pathway. This appendix states that the uncertainty in the health risk results for the groundwater pathway is approximately one or two orders of magnitude.

As shown in Table C.4–15, water quality comparison criteria used in the PEIS include maximum contaminant levels of the EPA National Primary Drinking Water Regulations (40 CFR 141) and standards for drinking water from DOE Order 5400.5 (DOE, 1990). Drinking water standards promulgated under the SDWA are applicable to treated drinking water at the tap and therefore do not directly apply to

***Table C.4–15. Water Quality Comparison Criteria***

| Constituent | EPA Drinking Water Regulations | | | DOE Derived Concentration Guides for Drinking Water[d] | EPA Quality Criteria for Fresh Water[e] | |
|---|---|---|---|---|---|---|
| | MCL[a] | SMCL[b] | Proposed MCL[c] | | Acute | Chronic |
| 1,2-Dichloroethane | 0.005 | | | | 118 | 20 |
| Actinium-227 | | | 1.27 | 0.4 | | |
| Americium-241 | | | 6.34 | 1.2 | | |
| Americium-242m | | | 1.27 | 1.2 | | |
| Americium-243 | | | 6.37 | 1.2 | | |
| Arsenic | 0.05 | | | | 0.36 | 0.19 |
| Barium | 1 | | | | | |
| Benzene | 0.005 | | | | 5.3 | |
| Cadmium | 0.005 | | | | 0.0039 | 0.0011 |
| Carbon Tetrachloride | 0.005 | | | | 35.2 | |
| Carbon-14 | | | 3,200 | 2,800 | | |
| Cesium-135 | | | 794 | 800 | | |
| Cesium-137 | | | 119 | 120 | | |
| Chromium +VI | 0.1 | | | | 0.016 | 0.011 |
| Curium-242 | | | 133 | 40 | | |
| Curium-244 | | | 9.84 | 2.4 | | |
| Curium-245 | | | 6.23 | 1.2 | | |
| Cyanide | 0.2 | | | | 0.022 | 0.0052 |
| Iodine-129 | | | 21 | 20 | | |
| Lead | 0.015[f] | | | | 0.082 | 0.0032 |
| Mercury | 0.002 | | | | 0.0024 | 0.000012 |
| Methylene Chloride | 0.005 | | | | | |
| Neptunium-237 | | | 7.06 | 1.2 | | |
| Nickel-59 | | | 27,000 | 28,000 | | |
| Nickel-63 | | | 9,910 | 12,000 | | |
| Palladium-107 | | | 36,600 | 40,000 | | |
| Plutonium-238 | | | 7.02 | 1.6 | | |
| Plutonium-239 | | | 62.1 | 1.2 | | |
| Plutonium-240 | | | 62.2 | 1.2 | | |
| Plutonium-241 | | | 62.6 | 80 | | |
| Potassium-40 | | | | 280 | | |
| Protactinium-231 | | | 10.2 | 0.4 | | |
| Radium-226 | 3[f] | | 20 | 4 | | |
| Samarium-151 | | | 14,100 | 16,000 | | |
| Selenium | 0.05 | | | | 0.26 | 0.035 |
| Selenium-79 | | | | 800 | | |
| Silver | | 0.1 | | | 0.0041 | 0.00012 |
| Strontium-90 | 8 | | 42 | 40 | | |
| Technetium-99 | | | 3,790 | 4,000 | | |
| Thorium-229 | | | 49.3 | 1.6 | | |
| Thorium-230 | | | 79.2 | 12 | | |
| Thorium-232 | | | 88 | 2 | | |

*Table C.4-15. Water Quality Comparison Criteria—Continued*

| Constituent | EPA Drinking Water Regulations | | | DOE Derived Concentration Guides for Drinking Water[d] | EPA Quality Criteria for Fresh Water[e] | |
|---|---|---|---|---|---|---|
| | MCL[a] | SMCL[b] | Proposed MCL[c] | | Acute | Chronic |
| Tin-126 (mg/L) | | | 293 | 320 | | |
| Uranium-233 (pCi/L) | | | 13.8 | 20 | | |
| Uranium-234 (pCi/L) | | | 13.9 | 20 | | |
| Uranium-235 (pCi/L) | | | 14.5 | 24 | | |
| Uranium-236 (pCi/L) | | | 14.7 | 20 | | |
| Uranium-238 (pCi/L) | | | 14.6 | 24 | | |
| Zirconium-93 (mg/L) | | | 5,090 | 3,600 | | |

Note: Blank cells indicate that no official standard or criterion exists for this constituent. MCL = maximum contaminant level. SMCL = secondary maximum contaminant level. Comparison criteria for 1,2,2-trichloro-1,1-trifluoroethane and acetone were not found.
[a] Source: 40 CFR 141, *National Primary Drinking Water Regulations*, and EPA (1991a).
[b] Source: 40 CFR 143, *National Secondary Drinking Water Regulations*. SMCLs based on taste and odor effects.
[c] Source: EPA (1991a). Concentration based on 4 mrem/year dose. Alpha emitters based on lifetime incidence risk of $1 \times 10^{-4}$.
[d] Source: DOE Order 5400.5 (DOE, 1990). Concentration based on 4 mrem/year effective dose equivalent.
[e] Source: EPA (1986).
[f] Action level.

groundwater quality. Since there are no Federal standards for groundwater quality protection, predicted concentrations of contaminants in the groundwater are compared with drinking water standards to indicate the level at which adverse impacts to water quality may occur. These criteria are commonly used as Applicable or Relevant and Appropriate Requirements (ARARs) to determine appropriate levels for groundwater cleanup under RCRA and CERCLA cleanup actions. Since drinking water standards adequately protect human health, groundwater contamination at or below these levels is considered to result in low risk to human health. EPA National Secondary Drinking Water Regulation secondary maximum contaminant levels (40 CFR 143) were used as comparison criteria where maximum contaminant levels did not exist, although they focus on qualities of taste and odor rather than protection of health.

The EPA proposed maximum contaminant levels for radionuclides in drinking water (EPA, 1991a) were not used because they are proposed regulations that are not yet in effect. Note that most of the EPA proposed drinking water standards for radionuclides are similar to the DOE derived concentration guides that were used. EPA quality criteria for fresh water (EPA, 1986) were not used since these apply primarily to surface water quality.

Federal water quality standards were used to provide a consistent means of comparison among sites. Using State water quality standards could bias the analysis toward sites with less stringent environmental laws.

This would be unfortunate since impacts occur in relation to the amount of contamination present. Impacts do not necessarily parallel regulation of the contamination.

It is important to note that DOE Order 5820.2A (DOE, 1988) for radioactive waste management, RCRA for hazardous waste, the Toxic Substances Control Act for waste containing PCBs, and DOE's Performance Assessment process would not allow a disposal facility to be constructed that would cause significant contamination of groundwater outside the facility boundary. If significant groundwater contamination was predicted by the Performance Assessment process, changes in the waste acceptance criteria would be made to limit disposal of the waste causing the problem. The wastes would require additional treatment prior to disposal, would be disposed at another DOE site where the wastes meet the waste acceptance criteria, or would be stored until a method was found to treat or dispose of the waste. In no case would DOE knowingly dispose of waste in violation of legal requirements.

Indirect impacts to water resources were deferred to site-specific or project-level NEPA documents. These include the effects of increased offsite water use caused by in-migrating employees and their families.

### C.4.4 Ecological Impacts Analysis Methods

Effects on ecological resources of waste treatment, storage, or disposal activities proposed at the 17 major DOE sites and the impacts of waste transportation were evaluated for each waste type under each alternative for:

- Routine activities of constructing and operating WM facilities
- Accidental releases of transported wastes

Table C.4–16 lists the ecological impact type, the particular resources affected, the general method used, the waste types to which each method was applied, and the type of presentation format for each ecological impact evaluated.

#### C.4.4.1 Routine WM Activity Impacts

The ecological impacts of routine WM activities were assessed in terms of potential disturbance or loss of nonsensitive terrestrial habitat resulting from site clearing for construction of WM facilities, the potential

*Table C.4-16. Ecological Resources Impacts Analyzed for the WM Alternatives*

| Ecological Impact Analyzed | Affected Ecological Resource | Impact Analysis Method | Applicable Waste Types | Presentation of Results |
|---|---|---|---|---|
| *Habitat Effects—Routine WM Activities* | | | | |
| Nonsensitive Habitat Loss | Terrestrial plants and animals | Comparison of habitat loss at WM construction sites to general habitat range | All five types | Text discussion |
| Potential for Sensitive Habitat Effects | Nearby wetlands and other sensitive habitats | Likelihood of impacts to nearby sensitive habitats by comparing construction acreage to available acreage of nonsensitive habitats | All five types | Text discussion |
| *Contaminant Exposures—Routine WM Activities* | | | | |
| Terrestrial Species Exposures | Terrestrial animal species | Comparison of estimated radiation dose of representative species with toxicity standard | LLMW, LLW, TRUW | Text discussion |
| *Habitat Effects or Contaminant Exposures—Routine WM Activities* | | | | |
| Sensitive Species Concerns | Federally and State-listed endangered and threatened species | Numbers of Federally and State-listed species displayed by site/alternative | All five types | Tabular listing |
| *Contaminant Exposures—Accidents* | | | | |
| Effects of Transportation Accidents | Aquatic Species in Streams crossing transportation corridors | Results of scenario-based modeling analysis of accidental spill effects on fish in various size streams | LLMW, LLW, TRUW | Text discussion |

for site clearing and WM facility operations to affect nearby sensitive habitats, and the potential for airborne contaminant releases from waste treatment facilities to be toxic to terrestrial wildlife.

### C.4.4.1.1 *Direct Nonsensitive Habitat Impacts*

During the construction phase, ecological resources will be affected through disturbance or loss of habitat resulting from site clearing. Terrestrial resources will be directly affected by land clearing through changes in vegetative cover, which will adversely affect the habitat of terrestrial animals.

These changes may be important for individual animals of certain species with limited home ranges, such as small mammals and songbirds. Likely impacts include increased direct mortality and susceptibility to predation. Individual animals with larger home ranges, such as game animals and raptors, may not be adversely affected by the decreases in vegetative cover resulting from site construction. In general, it is not expected that any nonsensitive species populations will be affected by the limited amounts of nonsensitive habitats lost or disturbed in the WM program. The discussion of the potential for these effects in the waste-type chapters draws a comparison between the limited amounts of acreage likely to be disturbed in managing the waste type at individual sites and the extent of the nonsensitive habitats available regionally.

#### C.4.4.1.2 *Indirect Sensitive Habitat Impacts*

Many of the DOE sites contain sensitive habitats. The degree to which those habitats would be unaffected by noise or vibration disturbance, human presence, vehicle or equipment emissions, runoff, or encroachment by nearby WM facility construction or operations activities at any site would depend on DOE's ability to avoid locating the facilities near the sensitive habitats. A measure of this ability is the percentage of available land that facility construction under any WM alternative would require at a site. Available acreage was estimated from site development plans either using land designated for waste operations or subtracting the acreage of existing structures and sensitive habitats, such as wetlands and wildlife management areas, from the total site acreage. Potential for impacts was assessed by estimating the percentage of available land by site and alternative and listing those that equal or exceed 1% in the waste-type chapters. Further evaluation of those sites where the percentage equals or exceeds 1% is presented in the waste-type chapters in terms of the expectation that DOE will be able to avoid impacts to sensitive habitats.

Aquatic resources may be indirectly affected through increased runoff and sedimentation loadings to surface waters from disturbed terrestrial areas. However, the use of various mitigation techniques should minimize potential facility construction impacts to aquatic ecological resources. Direct discharges of contaminants to surface waters from the routine operation of facilities are expected to be limited by engineering control practices. Therefore, impacts to aquatic organisms are expected to be minimal.

**Habitat Effects Data Sources**. Estimates of the acreage cleared to build WM facilities were compiled from the engineering analysis outputs described in Section C.3 of this appendix. For each waste type and WM

alternative, the total disturbed area was estimated by summing the plant area required for all WM facility modules (plus 25-foot buffer zones) and the parking area. Plant area was estimated as a function of waste throughput requirements, whereas, parking area was estimated on the approximate number of full-time plant employees. Available acreage was estimated using site development plans and site environmental reports.

**Habitat Effects Data Evaluation**. For nonsensitive habitat impacts, the construction acreage requirements at each site under each alternative are compared qualitatively with the general extent of these habitats in the affected regions.

For sensitive habitat impact evaluation, sites where the proposed construction activities would disturb more than 1% of the available WM area are noted in the waste-type chapters and additional discussion is included about whether these greater percentages would indicate that indirect effects to sensitive habitats are likely. Additional investigations of the type that would be conducted as part of the site-specific or project-level NEPA evaluations tiered to the PEIS, would be needed to confirm or refute any presumed significant habitat impacts.

### C.4.4.1.3 *Potential Toxicity to Terrestrial Wildlife*

The impacts of airborne releases of radionuclides and hazardous chemicals to terrestrial animals living near waste treatment facilities were estimated using atmospheric emission/deposition modeling. This modeling, which used the same atmospheric emissions estimates as used in the human health risk assessment, provided estimates of doses of radiological and nonradiological contaminants deposited onto near-field and far-field surface soils. The model also estimated uptake from the soils and transfer in a terrestrial food chain leading to exposure of a small mammal used as a model terrestrial receptor.

The white-footed mouse (*Peromyscus leucopus*) was used in this analysis to be representative of most small mammals because it is sensitive to contaminant exposure, it has a varied diet (for example, it eats both plants and insects), and it is a common prey species for a number of predators. In addition, field mice are ubiquitously distributed. These animals have a limited home range relative to estimated contaminant distributions. Therefore, mice live within potentially contaminated areas and can be expected to consume all of their diet from these areas.

#### C.4.4.1.3.1 Data Sources

Contaminant toxicity evaluations were conducted using the same estimates of waste treatment facility airborne emissions as were used in the human health risk analyses. These annual emission rate estimates, provided by ANL, were assumed to be constant over a 10-year operating period. Contaminants that accounted for up to 80% of total emissions were included in the assessment; trace emissions were not assessed.

Emission estimates were used as inputs to atmospheric dispersion/deposition models, which provided estimates of contaminant concentrations deposited to surface soils. Surface soil contaminants were then modeled for distribution in terrestrial food chains using a number of transfer factors.

Estimates of maximum near-field and far-field contaminant concentrations were developed in order to conservatively assess exposure. The pathways used to estimate internal and external exposure include direct exposure to external radiation, incidental soil ingestion, and uptake of contaminants from soils into terrestrial food chains. Exposure from the inhalation and water ingestion pathways was assumed to be minimal due to dilution.

Surface soil concentration estimates were developed for each contaminant by applying the maximum near-field and far-field deposition rates to the contaminant emission rates. Except for tritium, contaminants were conservatively assumed to accumulate in the soil over the 10-year operation period. Radioactive decay was accounted for in the analysis. Contaminants were assumed to be evenly distributed in the top six inches of soil.

Terrestrial food chain contaminant concentration estimates were made by applying transfer factors to soil concentrations to develop concentration estimates in plant tissues. Since reliable transfer factors were not available for estimating concentrations in insect tissue from plant tissue concentrations, complete (100%) plant to invertebrate transfer was conservatively assumed to estimate invertebrate tissue concentrations (ORNL, 1995b).

Tritium exposure was assessed separately. Tritiated water is the principal form of tritium in the environment. Therefore, tritium can be expected to be incorporated into a great variety of compounds but cannot be assumed to accumulate in soils. For tritium, a simplifying assumption was made that tritium

deposition is continuous and uniform over time and that tritium in the receptor mouse has attained a steady state equilibrium with environmental tritium (IAEA, 1992). Transfer factors for tritium were conservatively assumed to be 100% (ORNL, 1995b).

#### C.4.4.1.3.2 Data Evaluation

The potential toxicity of the radiological contaminants was assessed by comparing the estimated total internal and external doses to a benchmark value of 100 mrad/day, established by the International Atomic Energy Agency (IAEA, 1992). No-observable-adverse-effect levels (NOAELs) were used as benchmarks for the nonradiological (i.e., hazardous chemical) contaminants. The radionuclides selected for each analysis comprised 80% of the total volume of all radionuclides expected to be emitted at a given site. The radionuclides were used in calculating hazard indexes (HIs) for each selected site/alternative combination as composite ratios between the estimated species exposures to each of the contaminants and known, contaminant-specific toxic levels. The resulting ratio, the HI, was used to identify WM alternatives that may be of concern for potential ecotoxicity. An HI greater than one would indicate a potential for the combined exposures to adversely affect the health of terrestrial species. Hazardous and toxic chemicals were evaluated using a separate HI in the same way.

### C.4.4.1.4 *Potential Impacts to Sensitive Species*

Location-specific analyses would be required to address impacts to sensitive habitats and sensitive species, including species listed by the U.S. Fish and Wildlife Service as endangered or threatened. Those analyses would be part of the impacts analyses in NEPA documents tiered to this PEIS. For comparison of WM program effects on sensitive species, the waste-type chapters list the numbers of Federal and State-listed endangered and threatened species at each site under each alternative where a major action is proposed. Reference is made to the PEIS Chapter 4, Affected Environment, which lists the sensitive species at the 17 major sites.

### C.4.4.2 Impacts of Accidental Releases

The ecological impacts of waste transportation accidents were evaluated as consequence assessments of spills into aquatic environments. These assessments estimated the potential ecological impacts of transportation accidents involving varying size releases of radionuclides under certain spill scenarios. However, they do not include estimates of the probability of these events occurring.

Because hazardous constituents would vary so widely in volume and type in any particular mixed or hazardous waste shipment, no attempt was made to quantify the consequences of hazardous constituents in transportation accidents. Where applicable, the PEIS acknowledges that the consequences of those spills may be as severe or more severe than the consequences of spills of radioactive wastes.

Accidental spills in nonsensitive terrestrial environments were not quantified but are expected to have more limited consequences than those estimated for the aquatic scenarios because the extent of the affected area would be more limited to the immediate locality of the spill and cleanup would likely be more effective because of the stable nature of the affected substrate. Airborne contaminants released downwind through such accidents could affect terrestrial species through all routes of exposure. The effects of such releases on nearby exposed humans were evaluated and are presented in the PEIS waste-type chapters and the human health risk appendix (Appendix D). Terrestrial species would be at similar levels of risk for any acute effects.

Facility accidents would also likely affect terrestrial and aquatic environments on and near the affected site. Such accidents were evaluated for effects on human health. Ecological impacts are likely to be as severe as those shown in the human health effects analysis, however, no separate quantitative analysis of ecological impacts was done.

The transportation accident scenario used involves a rail shipment spill of waste directly into surface waters of different size classes. Assessments were performed for stream size classes ranging from a small second order stream (for example, flow rate of a few meters per second) to a tenth order major continental river (for example, the Mississippi River). Stream order is a method of numbering steams as part of a drainage basin network. The smallest tributary is called first order, the stream receiving the tributary is called second order, and so on. There are about 350,000 second-order streams in the United States and only one tenth-order stream, the Mississippi River.

The environmental fate of the spilled waste was evaluated under two assumptions. In one case, it was assumed that all spilled material remained suspended or dissolved in the water column and was transported downstream. Aquatic organisms present at any given location were assumed to be exposed for a maximum of four days to the maximum concentration of waste material. Contaminant concentrations would be reduced by longitudinal dispersion as the contaminants move downstream. Biota in the water column would receive an external exposure to suspended or dissolved radioisotopes.

In the other case, it was assumed that all of the released material was immediately deposited on the stream sediment at the release site. Aquatic organisms present at the release site were assumed to be exposed over their entire lifetime. Benthic (that is, bottom dwelling) biota would receive an external exposure from radiological waste deposited in sediment. If the deposited materials were allowed to remain in the sediment for a sufficient length of time, many isotopes would become incorporated into aquatic food chains. Food chain exposure would produce internal exposures for benthic organisms and for fish or other organisms that feed on them.

#### C.4.4.2.1 *Data Sources*

Estimates of the potential impacts of transportation accidents to aquatic organisms were conducted by Oak Ridge National Laboratory (ORNL, 1995b). ORNL used the waste load source term data provided by ANL as inputs to aquatic environmental fate models to estimate maximum credible radiological releases for transportation accidents involving HLW, LLW, and CH and RH TRUW. For each waste type, ANL provided information on the radionuclides and total activity present in a shipment and on the total release in a maximum severity accident. ANL concluded that for HLW and TRUW only a small portion of the total shipment inventory would be released because the only credible accidental release mechanisms for these waste types involve small cracks and seal failures in shipping containers. The entire contents of the LLW shipment were assumed to be released during a maximum severity accident; however, only a small fraction of the release was assumed to be soluble. The analysis of LLMW was based on the LLW results. Effects for HW and the chemical component of LLMW were not quantified as noted above (ANL, 1996a).

The source terms used in the assessment were obtained by screening the source terms from all sites for all alternatives for these waste types to identify the waste shipments that would result in the highest releases.

The environmental fate of the spilled contaminants was estimated using a two-dimensional aquatic chemical fate model (EPA, 1985c). It was assumed that all of the spilled material remained in the water column for transport downstream or to sediment (ORNL, 1995b).

#### C.4.4.2.2 *Data Evaluation*

For aquatic biota, adverse short-term effects (that is, acute toxicity) are assumed to occur if the estimated doses exceeded the maximum safe dose of one rad per day (rad/day) recommended by the National Council on Radiation Protection and Measurements (NCRP, 1991). The results of the water column assessment include estimates of (1) the length (meters) of the stream (for each size class) affected before longitudinal dispersion reduces the exposure below the NCRP threshold; and (2) the time (hours) required for this dispersion to occur.

The results of the sediment assessment include estimates of the amount (kilogram) of clean sediment needed to dilute the spilled material to a sediment activity level corresponding to a one rad/day lifetime dose to a large fish residing at the bottom of the stream and feeding on benthic biota. This value also should be a reasonable estimate of the amount of sediment that would have to be removed during a remedial action taken following the spill.

### C.4.5 Economic Impacts Analysis Methods

The economic impact analysis methods were used to estimate the economic impacts of the WM alternatives on the regional and National economies. The impacts assessment addressed potential changes in regional employment, personal income, and industry output due to WM expenditures at the 17 major sites (Table C.4–17). The assessment also addressed changes in National employment, personal income, and industry output due to the sum of spending on WM facility activities at all applicable sites and on waste transportation between sites under each waste type alternative. This section describes the analysis procedures, assumptions, data, evaluation techniques, and the presentation of the results from the economic impacts analysis.

***Table C.4–17. Economic Impacts Analyzed for the WM Alternatives***

| Economic Impact Analyzed | Affected Aspect of Economy | Impact Analysis Method | Presentation of Results |
|---|---|---|---|
| Effect on regional employment | Level of regional employment at the major sites | Proposed site expenditures multiplied by regional employment multiplier at each major site | Tabular or text-only depending on range of results |
| Effect on regional incomes | Level of regional personal income at the major sites | Proposed site expenditures multiplied by regional income multiplier at each major site | Tabular or text-only depending on range of results |
| Effect on regional industry output | Value of regional industrial production | Proposed site expenditures multiplied by regional income multiplier at each major site | Presented in Environmental Impacts Technical Report only |
| National economic effects | National employment, personal income, and industry output | Proposed site expenditures at all involved sites plus intersite transportation costs multiplied by national employment, income, and industry output multipliers | Text discussion |

### C.4.5.1 Focus of the Economic Impact Assessment

The economic impact analyses of the WM alternatives used a methodology that is standard for industrial construction projects, although the WM program presents several unique economic considerations because the WM facilities are designed to treat, store, and/or dispose of radioactive and hazardous waste. Because processing of these wastes requires substantial provisions to decrease the probability of harm to human health and the environment, special costs apply that include the costs of environmental documentation, for example, under Resource Conservation and Recovery Act (42 USC 6901 *et seq.*) and NEPA (42 USC 4321 *et seq.*), for monitoring, and for shielding.

The specific project expenditure categories include design and planning, testing, construction, cold start, O&M, D&D, and transportation. These expenditures and their respective time periods are not uniform across waste types. For example, there is no D&D phase for high-level waste. In the case of the alternatives for hazardous waste, there are expenditures proposed for commercial treatment, storage, and disposal facilities that factor into the National economy. Expenditures were aggregated into three major phases: construction, operations, and transportation. The construction phase encompasses all activities from the design phase through the cold start. The operations phase encompasses the O&M period as well as D&D. The transportation phase generally coincided with the O&M portion of the operations phase. The analysis

focused on the economic consequences of spending money on waste management activities within these major project phases. The full economic consequences of waste management activities were assumed to continue for an additional five years beyond the end of each phase (Cuthbertson and Nitzsche, 1994).

DOE recognizes the potential for economic effect on the ROI resulting from negative perceptions associated with its waste management program; for example, real estate property values in the vicinity of a radioactive waste disposal facility may decline, or the ability of the region to attract a diversified business base may be affected. However, although these potential impacts are recognized, they are not amenable to analysis at the programmatic level and in the absence of a specific location for the facility proposed. The nature and extent of such impacts is therefore not included in this PEIS.

### C.4.5.2 Quantitative Effects

The principal variables selected to characterize the regional and National economics and provide the baseline conditions for the 17 major sites—employment, per capita income, and population—are presented in Chapter 4. Per capita income was multiplied by population to calculate total personal income. Data for these variables are provided for 1990 in 1990 dollars.

The economic analysis employed three standard measures of change—employment, personal income, and industry output—as indicators of the potential impact of the WM alternatives. Changes in these indicators form the basis for the comparison of alternatives. Results of the analysis are presented both as absolute numbers and as changes over the 1990 baseline for the ROI as a whole. Since the absolute numbers are used, alternatives can be compared with each other in terms of absolute overall effect, independent of other, external changes in the prevailing conditions of the region of influence.

By comparing values for these indicators with the No Action and Decentralized Alternatives at a given site, the effect, in terms of a net change (either decrease or increase), can be determined for each of the other alternatives (see site tables, volume II). In addition to providing data on potential increases in these variables, the analysis also provides a basis for assessing the potential for losses in employment due to the shifting of work away from the site. This is available in the existing analysis as a comparison of the effects presented for the Decentralized or No Action Alternatives with the remaining alternatives.

The economic impact analysis estimated changes in employment, personal income, and industry output that would result from the direct infusion of project dollars into the regional and national economies and subsequent multiple cycles of spending. The following definitions of these variables apply to both the affected environment and impact chapters of the PEIS.

### C.4.5.2.1 *Employment*

One of the variables that the economic impacts generated by the model described below is "job-years." The variable "job-years" is equivalent to person-years, or full-time equivalents. One job-year is equal to 2,080 hours of employment in a twelve month period. Employment is the count of full- and part-time jobs. Job-years is converted to jobs or employment by dividing the number of job-years by the number of years over which the initial expenditures take place, plus the additional time it takes for the successive rounds of expenditure to occur (i.e., five years for each phase).

Employment impacts are presented according to place of work. Employment by place of work shows how many people work in a given region irrespective of where they live. The workforce of a regional economy is considered to be the number of people that work in a given region (as opposed to the number of people that live and work in the region). The economic impact analysis is geared to determine what the change in direct, indirect, and induced employment would be given a change in expenditures in the region. The research question is one of how many jobs will be generated in total, not how many jobs will be generated for the people that live in a given county.

The employment by place of residence shows how many people in a given region (a county or aggregation of counties) have jobs, irrespective of which region their jobs are in. The affected environment chapter in the PEIS (Chapter 4) provides employment by place of residence for the 17 major DOE sites. The ratio of the site workforce to employment by place of residence is an indicator of regional economic dependence on DOE sites. If there were a change in the number of jobs at a site, the change in the unemployment rate would be reported by where people live, not work.

While the data will indicate the direction of change, information on the magnitude of the changes will be more vague. It will be difficult to gauge the change in the unemployment rates due to a change in waste management spending, for example, but estimates of the magnitude of change in employment can be given. The percentage of earnings to labor from each of the "division level" Standard Industrial Classification

(SIC) codes gives a useful snapshot of the character of the economy, but it will not be possible to determine how the composition of labor earnings will change given the implementation of one of the alternatives at a site. This is because the programmatic level of analysis must focus on a level of detail that enables a comparison of alternatives across sites and waste types. Analyzing changes in the composition of earnings obscures the importance of variables that facilitate a meaningful comparison of alternatives.

Baseline employment (by place of work) and baseline personal income for every ROI has been extracted from the U.S. Bureau of Economic Analysis' Regional Economic Information System (DOC, 1992a) and is presented in Tables C.4–18 and C.4–19.

### C.4.5.2.2 *Personal Income*

Total personal income is defined as pre-tax disposable income to the household sector. It is useful as a measure of the purchasing power available to consumers. The impacts analysis uses a measure of income that subtracts taxes out of the first cycle of spending. While the two measures are not identically defined, the numbers are similar enough that they can be combined.

### C.4.5.2.3 *Industry Output*

Output is defined as gross industry receipts (DOC, 1992b), i.e., the number of units of goods and services that are sold times the price per unit. Output is useful in illustrating the magnitude of economic activity in a given region or in the national economy. Output, however, has two important limitations:

- Output includes the revenues for each cycle of expenditure. Therefore, the value of a given good or service may be accumulated several times as an intermediate good before it is ultimately sold as a final good to the consumer.
- Baseline measures of output are not available at the regional level. The model used to determine impacts provides a change in output given a change in initial expenditures, but data are not available to compute a percent change in the baseline output.

## *Table C.4–18. Baseline Employment Data*

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| Ames | Boone (IA) | 10,266 | 11,351 | 11,684 | 11,006 | 11,205 | 9.1% |
| | Hamilton (IA) | 8,237 | 8,969 | 9,427 | 9,418 | 10,210 | 24.0% |
| | Hardin (IA) | 10,110 | 10,809 | 11,822 | 11,290 | 11,323 | 12.0% |
| | Jasper (IA) | 15,997 | 16,390 | 16,889 | 16,770 | 17,823 | 11.4% |
| | Marshall (IA) | 20,632 | 22,377 | 23,519 | 21,779 | 23,065 | 11.8% |
| | Polk (IA) | 157,758 | 179,201 | 206,377 | 216,637 | 255,686 | 62.1% |
| | Story (IA) | 28,296 | 33,610 | 40,419 | 42,245 | 46,365 | 63.9% |
| | | 251,296 | 282,707 | 320,137 | 329,145 | 375,677 | 49.5% |
| ANL-E | Cook (IL) | 2,780,014 | 2,742,358 | 2,873,797 | 2,885,969 | 3,080,458 | 10.8% |
| | Du Page (IL) | 154,520 | 215,484 | 282,623 | 382,481 | 510,994 | 230.7% |
| | Kane (IL) | 108,159 | 117,301 | 131,252 | 141,234 | 171,116 | 58.2% |
| | Will (IL) | 87,178 | 90,369 | 100,401 | 104,134 | 121,273 | 39.1% |
| | | 3,129,871 | 3,165,512 | 3,388,073 | 3,513,818 | 3,883,841 | 24.1% |
| BCL | Delaware (OH) | 15,851 | 17,914 | 21,449 | 23,432 | 27,026 | 70.5% |
| | Fairfield (OH) | 27,211 | 30,877 | 36,655 | 35,308 | 38,948 | 43.1% |
| | Franklin (OH) | 399,431 | 447,635 | 512,397 | 576,164 | 680,737 | 70.4% |
| | Licking (OH) | 41,660 | 43,642 | 50,269 | 52,119 | 56,828 | 36.4% |
| | Madison (OH) | 9,124 | 9,763 | 10,205 | 10,262 | 13,287 | 45.6% |
| | Pickaway (OH) | 14,546 | 16,037 | 17,188 | 16,031 | 17,800 | 22.4% |
| | Union (OH) | 10,672 | 11,289 | 12,486 | 15,042 | 22,671 | 112.4% |
| | | 518,495 | 577,157 | 660,649 | 728,358 | 857,297 | 65.3% |
| Bettis | Allegheny (PA) | 730,822 | 731,255 | 765,235 | 742,910 | 802,173 | 9.8% |
| | Armstrong (PA) | 22,139 | 24,075 | 24,607 | 23,111 | 24,280 | 9.7% |
| | Beaver (PA) | 81,428 | 87,386 | 86,106 | 64,258 | 62,093 | -23.7% |
| | Butler (PA) | 46,384 | 49,600 | 56,201 | 56,647 | 67,382 | 45.3% |
| | Washington (PA) | 71,399 | 77,275 | 79,039 | 73,958 | 80,823 | 13.2% |
| | Westmoreland (PA) | 123,374 | 131,997 | 147,434 | 141,501 | 151,582 | 22.9% |
| | | 1,075,546 | 1,101,588 | 1,158,622 | 1,102,385 | 1,188,333 | 10.5% |
| BNL | Nassau (NY) | 556,601 | 581,113 | 648,039 | 749,839 | 771,414 | 38.6% |
| | Suffolk (NY) | 317,836 | 378,992 | 470,017 | 586,728 | 647,626 | 103.8% |
| | | 874,437 | 960,105 | 1,118,056 | 1,336,567 | 1,419,040 | 62.3% |
| Charleston | Berkeley (SC) | 12,091 | 15,250 | 23,617 | 27,331 | 33,869 | 180.1% |
| | Charleston (SC) | 130,125 | 147,319 | 167,296 | 196,497 | 226,839 | 74.3% |
| | Colleton (SC) | 10,507 | 10,942 | 11,591 | 12,568 | 13,805 | 31.4% |
| | Dorchester (SC) | 8,701 | 11,782 | 15,983 | 21,662 | 25,392 | 191.8% |
| | | 161,424 | 185,293 | 218,487 | 258,058 | 299,905 | 85.8% |
| Colonie | Albany (NY) | 179,332 | 183,478 | 203,657 | 225,005 | 256,215 | 42.9% |
| | Columbia (NY) | 17,950 | 19,455 | 20,598 | 22,942 | 25,561 | 42.4% |
| | Greene (NY) | 11,675 | 13,144 | 14,306 | 15,456 | 17,034 | 45.9% |
| | Rensselaer (NY) | 44,314 | 44,726 | 46,767 | 52,406 | 61,152 | 38.0% |
| | Saratoga (NY) | 30,254 | 35,894 | 44,418 | 54,378 | 68,058 | 125.0% |
| | Schenectady (NY) | 71,461 | 75,442 | 75,567 | 75,564 | 79,628 | 11.4% |
| | Schoharie (NY) | 7,799 | 8,514 | 8,656 | 9,267 | 10,655 | 36.6% |
| | | 362,785 | 380,653 | 413,969 | 455,018 | 518,303 | 42.9% |
| ETEC | Kern (CA) | 136,096 | 166,838 | 198,411 | 231,191 | 259,475 | 90.7% |
| | Los Angeles (CA) | 3,326,115 | 3,551,891 | 4,272,799 | 4,661,161 | 5,199,569 | 56.3% |
| | San Luis Obispo (CA) | 37,913 | 48,874 | 65,028 | 83,929 | 103,621 | 173.3% |
| | Santa Barbara (CA) | 113,665 | 134,333 | 163,668 | 193,381 | 213,960 | 88.2% |
| | Ventura (CA) | 131,954 | 166,800 | 216,109 | 259,345 | 320,927 | 143.2% |
| | | 3,745,743 | 4,068,736 | 4,916,015 | 5,429,007 | 6,097,552 | 62.8% |
| Fermi | Cook (IL) | 2,780,014 | 2,742,358 | 2,873,797 | 2,885,969 | 3,080,458 | 10.8% |
| | De Kalb (IL) | 31,128 | 31,702 | 34,187 | 35,438 | 38,832 | 24.7% |
| | Du Page (IL) | 154,520 | 215,484 | 282,623 | 382,481 | 510,994 | 230.7% |
| | Kane (IL) | 108,159 | 117,301 | 131,252 | 141,234 | 171,116 | 58.2% |
| | Kendall (IL) | 13,871 | 16,224 | 17,041 | 13,700 | 10,763 | -22.4% |
| | McHenry (IL) | 41,314 | 46,505 | 55,262 | 65,007 | 81,866 | 98.2% |
| | Will (IL) | 87,178 | 90,369 | 100,401 | 104,134 | 121,273 | 39.1% |
| | | 3,216,184 | 3,259,943 | 3,494,563 | 3,627,963 | 4,015,302 | 24.8% |
| FEMP | Butler (OH) | 82,804 | 87,339 | 99,638 | 103,659 | 115,182 | 39.1% |
| | Hamilton (OH) | 488,962 | 490,210 | 540,620 | 562,639 | 630,991 | 29.0% |
| | Warren (OH) | 17,209 | 21,622 | 27,641 | 31,891 | 44,723 | 159.9% |
| | Dearborn (IN) | 10,779 | 11,322 | 12,629 | 12,114 | 13,480 | 25.1% |
| | | 599,754 | 610,493 | 680,528 | 710,303 | 804,376 | 34.1% |

## *Table C.4-18. Baseline Employment Data—Continued*

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| GA | Imperial (CA) | 33,842 | 41,879 | 45,988 | 40,725 | 52,289 | 54.5% |
| | Orange (CA) | 531,119 | 711,851 | 1,038,731 | 1,271,121 | 1,552,291 | 192.3% |
| | Riverside (CA) | 166,660 | 192,861 | 256,835 | 317,421 | 436,293 | 161.8% |
| | San Diego (CA) | 633,738 | 733,668 | 963,302 | 1,154,677 | 1,396,552 | 120.4% |
| | | 1,365,359 | 1,680,259 | 2,304,856 | 2,783,944 | 3,437,425 | 151.8% |
| GE | Alpine (CA) | 200 | 248 | 520 | 707 | 802 | 301.0% |
| | Amador (CA) | 4,720 | 5,839 | 7,656 | 9,173 | 11,974 | 153.7% |
| | Calaveras (CA) | 4,618 | 4,743 | 7,524 | 8,880 | 10,610 | 129.8% |
| | San Joaquin (CA) | 123,076 | 139,076 | 162,927 | 181,349 | 211,109 | 71.5% |
| | Stanislaus (CA) | 81,872 | 98,597 | 121,735 | 132,122 | 166,656 | 103.6% |
| | Tuolumne (CA) | 7,473 | 9,570 | 13,817 | 16,582 | 20,641 | 176.2% |
| | | 221,959 | 258,073 | 314,179 | 348,813 | 421,792 | 90.0% |
| GJPO | Delta (CO) | 5,515 | 6,599 | 8,667 | 9,155 | 9,506 | 72.4% |
| | Garfield (CO) | 5,783 | 8,747 | 11,873 | 14,554 | 17,224 | 197.8% |
| | Gunnison (CO) | 2,664 | 3,979 | 6,163 | 6,263 | 7,041 | 164.3% |
| | Mesa (CO) | 22,275 | 29,506 | 42,466 | 43,106 | 48,064 | 115.8% |
| | Montrose (CO) | 7,025 | 8,806 | 11,649 | 11,460 | 13,141 | 87.1% |
| | Pitkin (CO) | 4,231 | 7,865 | 11,529 | 12,764 | 16,546 | 291.1% |
| | Grand (UT) | 2,675 | 3,032 | 4,045 | 2,955 | 3,122 | 16.7% |
| | | 50,168 | 68,534 | 96,392 | 100,257 | 114,644 | 128.5% |
| Hanford | Adams (WA) | 6,976 | 7,602 | 8,076 | 7,894 | 8,409 | 20.5% |
| | Benton (WA) | 27,477 | 38,013 | 58,925 | 54,409 | 59,910 | 118.0% |
| | Franklin (WA) | 12,743 | 15,528 | 18,414 | 17,177 | 21,129 | 65.8% |
| | Grant (WA) | 18,323 | 22,333 | 23,340 | 23,904 | 26,950 | 47.1% |
| | Yakima (WA) | 62,556 | 71,326 | 82,024 | 84,284 | 97,900 | 56.5% |
| | | 128,075 | 154,802 | 190,779 | 187,668 | 214,298 | 67.3% |
| INEL | Bannock (ID) | 20,961 | 26,185 | 30,628 | 30,386 | 30,078 | 43.5% |
| | Bingham (ID) | 12,362 | 14,051 | 15,150 | 15,679 | 16,758 | 35.6% |
| | Bonneville (ID) | 22,232 | 26,706 | 31,452 | 33,436 | 38,092 | 71.3% |
| | Butte (ID) | 4,287 | 5,347 | 6,625 | 7,054 | 7,934 | 85.1% |
| | Clark (ID) | 463 | 539 | 602 | 584 | 679 | 46.7% |
| | Jefferson (ID) | 4,221 | 4,953 | 5,603 | 5,470 | 6,151 | 45.7% |
| | | 64,526 | 77,781 | 90,060 | 92,609 | 99,692 | 54.5% |
| KCP | Cass (MO) | 13,222 | 15,139 | 14,298 | 17,627 | 20,904 | 58.1% |
| | Clay (MO) | 40,959 | 42,843 | 51,268 | 66,683 | 77,616 | 89.5% |
| | Jackson (MO) | 385,262 | 390,795 | 424,126 | 430,173 | 441,174 | 14.5% |
| | Johnson (MO) | 14,493 | 16,243 | 17,867 | 19,173 | 21,770 | 50.2% |
| | Lafayette (MO) | 10,684 | 11,221 | 12,036 | 12,253 | 13,439 | 25.8% |
| | Ray (MO) | 4,662 | 5,357 | 5,736 | 6,583 | 6,784 | 45.5% |
| | Johnson (KS) | 70,399 | 98,553 | 141,148 | 185,482 | 242,894 | 245.0% |
| | Wyandotte (KS) | 81,896 | 87,583 | 92,056 | 93,354 | 91,892 | 12.2% |
| | | 621,577 | 667,734 | 758,535 | 831,328 | 916,473 | 47.4% |
| KAPL-K | Fulton (NY) | 18,714 | 18,882 | 19,715 | 20,262 | 21,167 | 13.1% |
| | Saratoga (NY) | 30,254 | 35,894 | 44,418 | 54,378 | 68,058 | 125.0% |
| | Schenectady (NY) | 71,461 | 75,442 | 75,567 | 75,564 | 79,628 | 11.4% |
| | | 120,429 | 130,218 | 139,700 | 150,204 | 168,853 | 40.2% |
| KAPL-N | Albany (NY) | 179,332 | 183,478 | 203,657 | 225,005 | 256,215 | 42.9% |
| | Montgomery (NY) | 22,062 | 20,904 | 22,387 | 23,284 | 24,092 | 9.2% |
| | Saratoga (NY) | 30,254 | 35,894 | 44,418 | 54,378 | 68,058 | 125.0% |
| | Schenectady (NY) | 71,461 | 75,442 | 75,567 | 75,564 | 79,628 | 11.4% |
| | Schoharie (NY) | 7,799 | 8,514 | 8,656 | 9,267 | 10,655 | 36.6% |
| | | 310,908 | 324,232 | 354,685 | 387,498 | 438,648 | 41.1% |
| KAPL-W | Hartford (CT) | 438,369 | 452,340 | 527,904 | 572,596 | 615,574 | 40.4% |
| | Litchfield (CT) | 53,720 | 56,711 | 68,844 | 76,288 | 85,810 | 59.7% |
| | Middlesex (CT) | 45,352 | 51,689 | 60,868 | 73,741 | 82,460 | 81.8% |
| | New Haven (CT) | 337,150 | 345,124 | 380,393 | 414,784 | 444,307 | 31.8% |
| | Tolland (CT) | 26,124 | 29,700 | 33,363 | 39,941 | 48,387 | 85.2% |
| | Hampden (MA) | 202,106 | 198,347 | 220,977 | 229,234 | 240,374 | 18.9% |
| | | 1,102,821 | 1,133,911 | 1,292,349 | 1,406,584 | 1,516,912 | 37.5% |

### *Table C.4–18. Baseline Employment Data—Continued*

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| LEHR | Colusa (CA) | 6,205 | 7,138 | 7,112 | 6,942 | 7,891 | 27.2% |
| | Lake (CA) | 6,677 | 8,708 | 11,881 | 15,251 | 17,218 | 157.9% |
| | Napa (CA) | 26,918 | 34,555 | 42,081 | 48,591 | 58,321 | 116.7% |
| | Sacramento (CA) | 276,010 | 320,242 | 396,980 | 485,139 | 603,669 | 118.7% |
| | Solano (CA) | 76,418 | 82,069 | 96,464 | 111,163 | 134,353 | 75.8% |
| | Sutter (CA) | 15,427 | 19,256 | 22,441 | 22,643 | 26,725 | 73.2% |
| | Yolo (CA) | 34,958 | 47,963 | 57,528 | 64,323 | 82,075 | 134.8% |
| | | 442,613 | 519,931 | 634,487 | 754,052 | 930,252 | 110.2% |
| LBL | Alameda (CA) | 490,578 | 509,946 | 588,728 | 656,286 | 738,160 | 50.5% |
| | Contra Costa (CA) | 170,808 | 202,758 | 262,043 | 321,605 | 396,508 | 132.1% |
| | | 661,386 | 712,704 | 850,771 | 977,891 | 1,134,668 | 71.6% |
| LLNL | Alameda (CA) | 490,578 | 509,946 | 588,728 | 656,286 | 738,160 | 50.5% |
| | Contra Costa (CA) | 170,808 | 202,758 | 262,043 | 321,605 | 396,508 | 132.1% |
| | San Joaquin (CA) | 123,076 | 139,076 | 162,927 | 181,349 | 211,109 | 71.5% |
| | Stanislaus (CA) | 81,872 | 98,597 | 121,735 | 132,122 | 166,656 | 103.6% |
| | | 866,334 | 950,377 | 1,135,433 | 1,291,362 | 1,512,433 | 74.6% |
| LANL | Los Alamos (NM) | 8,802 | 10,950 | 14,010 | 16,831 | 18,066 | 105.2% |
| | Rio Arriba (NM) | 6,505 | 7,006 | 8,303 | 9,377 | 10,341 | 59.0% |
| | Santa Fe (NM) | 22,125 | 28,707 | 36,708 | 46,045 | 55,088 | 149.0% |
| | | 37,432 | 46,663 | 59,021 | 72,253 | 83,495 | 123.1% |
| Mare Island | Contra Costa (CA) | 170,808 | 202,758 | 262,043 | 321,605 | 396,508 | 132.1% |
| | Lake (CA) | 6,677 | 8,708 | 11,881 | 15,251 | 17,218 | 157.9% |
| | Marin (CA) | 68,350 | 81,672 | 105,136 | 131,293 | 149,704 | 119.0% |
| | Mendocino (CA) | 19,826 | 24,124 | 32,118 | 35,191 | 41,643 | 110.0% |
| | Napa (CA) | 26,918 | 34,555 | 42,081 | 48,591 | 58,321 | 116.7% |
| | Sonoma (CA) | 71,368 | 93,149 | 129,858 | 162,799 | 200,809 | 181.4% |
| | | 363,947 | 444,966 | 583,117 | 714,730 | 864,203 | 137.5% |
| Middlesex | Mercer (NJ) | 152,536 | 163,220 | 180,825 | 197,963 | 218,289 | 43.1% |
| | Middlesex (NJ) | 236,060 | 264,873 | 317,105 | 362,229 | 410,340 | 73.8% |
| | Monmouth (NJ) | 156,505 | 173,172 | 205,799 | 247,685 | 278,379 | 77.9% |
| | Somerset (NJ) | 73,129 | 87,696 | 110,237 | 138,071 | 162,850 | 122.7% |
| | Union (NJ) | 289,170 | 276,194 | 298,539 | 312,241 | 298,021 | 3.1% |
| | | 907,400 | 965,155 | 1,112,505 | 1,258,189 | 1,367,879 | 50.7% |
| Mound | Butler (OH) | 82,804 | 87,339 | 99,638 | 103,659 | 115,182 | 39.1% |
| | Clark (OH) | 54,155 | 54,702 | 58,828 | 58,685 | 64,883 | 19.8% |
| | Darke (OH) | 17,601 | 19,586 | 20,840 | 21,516 | 23,698 | 34.6% |
| | Greene (OH) | 38,914 | 41,134 | 45,604 | 51,345 | 61,164 | 57.2% |
| | Miami (OH) | 33,836 | 35,269 | 41,309 | 41,334 | 45,711 | 35.1% |
| | Montgomery (OH) | 310,229 | 296,176 | 319,744 | 336,040 | 365,015 | 17.7% |
| | Preble (OH) | 9,686 | 10,484 | 11,389 | 12,650 | 13,803 | 42.5% |
| | Warren (OH) | 17,209 | 21,622 | 27,641 | 31,891 | 44,723 | 159.9% |
| | | 564,434 | 566,312 | 624,993 | 657,120 | 734,179 | 30.1% |
| NTS | Clark (NV) | 131,904 | 171,122 | 261,135 | 301,329 | 441,267 | 234.5% |
| | Nye (NV) | 7,140 | 5,794 | 7,819 | 11,071 | 12,763 | 78.8% |
| | | 139,044 | 176,916 | 268,954 | 312,400 | 454,030 | 226.5% |
| Norfolk | Chesapeake city (VA) | 22,046 | 24,449 | 31,494 | 41,790 | 60,021 | 172.3% |
| | Hampton city (VA) | 49,777 | 52,385 | 60,119 | 69,468 | 74,278 | 49.2% |
| | Newport News city (VA) | 74,805 | 78,736 | 84,006 | 96,784 | 108,988 | 45.7% |
| | Norfolk city (VA) | 209,849 | 211,839 | 225,741 | 245,270 | 256,042 | 22.0% |
| | Suffolk city (VA) | 17,837 | 19,957 | 19,391 | 19,414 | 20,545 | 15.2% |
| | Virginia Beach city (VA) | 64,219 | 77,602 | 106,903 | 151,809 | 182,932 | 184.9% |
| | Isle of Wight (VA) | 9,222 | 9,781 | 11,791 | 11,380 | 12,346 | 33.9% |
| | | 447,755 | 474,749 | 539,445 | 635,915 | 715,152 | 59.7% |
| ORR | Anderson (TN) | 20,457 | 24,385 | 30,785 | 32,310 | 39,083 | 91.1% |
| | Knox (TN) | 123,389 | 143,530 | 174,676 | 187,012 | 212,347 | 72.1% |
| | Loudon (TN) | 8,434 | 9,012 | 9,966 | 10,694 | 12,310 | 46.0% |
| | Roane (TN) | 21,217 | 21,211 | 23,362 | 22,289 | 24,234 | 14.2% |
| | | 173,497 | 198,138 | 238,789 | 252,305 | 287,974 | 66.0% |

## *Table C.4-18. Baseline Employment Data—Continued*

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| PGDP | Ballard (KY) | 3,139 | 3,344 | 3,812 | 3,603 | 3,868 | 23.2% |
| | Carlisle (KY) | 1,911 | 1,814 | 1,768 | 1,798 | 1,802 | -5.7% |
| | Graves (KY) | 12,550 | 13,566 | 13,549 | 13,552 | 15,312 | 22.0% |
| | Marshall (KY) | 9,121 | 9,125 | 10,705 | 10,901 | 12,773 | 40.0% |
| | McCracken (KY) | 27,167 | 31,027 | 34,536 | 34,007 | 41,056 | 51.1% |
| | Massac (IL) | 4,776 | 5,078 | 5,267 | 4,666 | 4,945 | 3.5% |
| | | 58,664 | 63,954 | 69,637 | 68,527 | 79,756 | 36.0% |
| Palos | Cook (IL) | 2,780,014 | 2,742,358 | 2,873,797 | 2,885,969 | 3,080,458 | 10.8% |
| | Du Page (IL) | 154,520 | 215,484 | 282,623 | 382,481 | 510,994 | 230.7% |
| | Kane (IL) | 108,159 | 117,301 | 131,252 | 141,234 | 171,116 | 58.2% |
| | Lake (IL) | 164,074 | 177,608 | 206,965 | 238,950 | 292,353 | 78.2% |
| | McHenry (IL) | 41,314 | 46,505 | 55,262 | 65,007 | 81,866 | 98.2% |
| | Will (IL) | 87,178 | 90,369 | 100,401 | 104,134 | 121,273 | 39.1% |
| | Lake (IN) | 228,285 | 227,217 | 237,925 | 205,496 | 228,304 | 0.0% |
| | | 3,563,544 | 3,616,842 | 3,888,225 | 4,023,271 | 4,486,364 | 25.9% |
| Pantex | Carson (TX) | 4,536 | 4,681 | 4,619 | 5,279 | 4,956 | 9.3% |
| | Potter (TX) | 55,811 | 68,372 | 77,990 | 86,106 | 78,713 | 41.0% |
| | Randall (TX) | 9,502 | 11,954 | 14,554 | 18,663 | 20,585 | 116.6% |
| | | 69,849 | 85,007 | 97,163 | 110,048 | 104,254 | 49.3% |
| Pearl H | Honolulu (HI) | 354,084 | 400,793 | 454,443 | 474,056 | 540,449 | 52.6% |
| | Kauai (HI) | 13,518 | 16,252 | 21,278 | 23,900 | 31,820 | 135.4% |
| | Maui (HI) | 21,023 | 27,778 | 38,034 | 47,507 | 63,110 | 200.2% |
| | | 388,625 | 444,823 | 513,755 | 545,463 | 635,379 | 63.5% |
| Pinellas | Hillsborough (FL) | 219,555 | 276,643 | 334,297 | 443,567 | 534,096 | 143.3% |
| | Pasco (FL) | 17,603 | 30,096 | 46,570 | 66,730 | 83,624 | 375.1% |
| | Pinellas (FL) | 185,693 | 232,451 | 307,786 | 400,674 | 457,517 | 146.4% |
| | | 422,851 | 539,190 | 688,653 | 910,971 | 1,075,237 | 154.3% |
| PORTS | Jackson (OH) | 8,995 | 9,430 | 9,911 | 11,328 | 11,560 | 28.5% |
| | Pike (OH) | 6,030 | 7,300 | 9,135 | 9,481 | 9,876 | 63.8% |
| | Ross (OH) | 23,046 | 23,172 | 26,441 | 27,342 | 28,598 | 24.1% |
| | Scioto (OH) | 26,467 | 24,934 | 26,633 | 25,617 | 27,772 | 4.9% |
| | | 64,538 | 64,836 | 72,120 | 73,768 | 77,806 | 20.6% |
| Ports Nav | Cumberland (ME) | 97,734 | 107,768 | 126,806 | 151,907 | 183,271 | 87.5% |
| | Oxford (ME) | 17,305 | 18,085 | 21,598 | 20,341 | 23,304 | 34.7% |
| | York (ME) | 46,430 | 48,463 | 60,765 | 72,106 | 83,380 | 79.6% |
| | Carroll (NH) | 8,070 | 10,525 | 14,020 | 18,809 | 23,172 | 187.1% |
| | Rockingham (NH) | 49,342 | 60,202 | 89,598 | 117,970 | 134,660 | 172.9% |
| | Strafford (NH) | 30,189 | 31,769 | 40,538 | 44,984 | 50,420 | 67.0% |
| | | 249,070 | 276,812 | 353,325 | 426,117 | 498,207 | 100.0% |
| PPPL | Burlington (NJ) | 135,712 | 127,481 | 142,828 | 175,494 | 202,936 | 49.5% |
| | Hunterdon (NJ) | 24,227 | 27,383 | 32,991 | 44,645 | 52,433 | 116.4% |
| | Mercer (NJ) | 152,536 | 163,220 | 180,825 | 197,963 | 218,289 | 43.1% |
| | Middlesex (NJ) | 236,060 | 264,873 | 317,105 | 362,229 | 410,340 | 73.8% |
| | Monmouth (NJ) | 156,505 | 173,172 | 205,799 | 247,685 | 278,379 | 77.9% |
| | Somerset (NJ) | 73,129 | 87,696 | 110,237 | 138,071 | 162,850 | 122.7% |
| | Bucks (PA) | 137,592 | 163,917 | 199,483 | 234,165 | 266,078 | 93.4% |
| | | 915,761 | 1,007,742 | 1,189,268 | 1,400,252 | 1,591,305 | 73.8% |
| Puget So | Jefferson (WA) | 3,628 | 4,405 | 6,183 | 7,114 | 9,117 | 151.3% |
| | King (WA) | 537,408 | 605,581 | 804,356 | 901,911 | 1,131,447 | 110.5% |
| | Kitsap (WA) | 44,510 | 50,766 | 66,838 | 78,435 | 95,238 | 114.0% |
| | Mason (WA) | 6,919 | 8,067 | 10,767 | 11,274 | 13,333 | 92.7% |
| | Pierce (WA) | 184,149 | 178,218 | 207,284 | 234,443 | 269,479 | 46.3% |
| | | 776,614 | 847,037 | 1,095,428 | 1,233,177 | 1,518,614 | 95.5% |
| RMI | Ashtabula (OH) | 37,633 | 38,012 | 40,731 | 38,646 | 38,878 | 3.3% |
| | Geauga (OH) | 15,640 | 18,878 | 23,400 | 28,035 | 32,720 | 109.2% |
| | Lake (OH) | 62,584 | 72,178 | 86,842 | 90,650 | 103,431 | 65.3% |
| | Trumbull (OH) | 95,326 | 102,895 | 107,783 | 102,098 | 105,424 | 10.6% |
| | Crawford (PA) | 32,380 | 34,817 | 36,833 | 36,586 | 39,330 | 21.5% |
| | Erie (PA) | 115,493 | 129,015 | 132,838 | 130,760 | 143,588 | 24.3% |
| | | 359,056 | 395,795 | 428,427 | 426,775 | 463,371 | 29.1% |

## Table C.4–18. Baseline Employment Data—Continued

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| RFETS | Adams (CO) | 47,558 | 72,721 | 97,335 | 113,176 | 126,465 | 165.9% |
| | Arapahoe (CO) | 48,565 | 87,125 | 132,994 | 191,619 | 218,287 | 349.5% |
| | Boulder (CO) | 53,430 | 76,151 | 110,011 | 139,658 | 157,460 | 194.7% |
| | Denver (CO) | 379,312 | 399,634 | 480,031 | 510,784 | 469,920 | 23.9% |
| | Jefferson (CO) | 68,124 | 109,812 | 154,901 | 207,232 | 226,393 | 232.3% |
| | | 596,989 | 745,443 | 975,272 | 1,162,469 | 1,198,525 | 100.8% |
| SNL/NM | Bernalillo (NM) | 135,635 | 176,533 | 219,901 | 266,864 | 304,985 | 124.9% |
| | Cibola (NM) | 0 | 0 | 0 | 5,358 | 6,148 | NA |
| | Sandoval (NM) | 3,323 | 4,386 | 5,495 | 8,987 | 12,734 | 283.2% |
| | Santa Fe (NM) | 22,125 | 28,707 | 36,708 | 46,045 | 55,088 | 149.0% |
| | Torrance (NM) | 1,879 | 2,046 | 2,182 | 2,496 | 2,957 | 57.4% |
| | Valencia (NM) | 9,110 | 12,208 | 17,661 | 9,695 | 11,486 | 26.1% |
| | | 172,072 | 223,880 | 281,947 | 339,445 | 393,398 | 128.6% |
| SRS | Aiken (SC) | 35,181 | 38,587 | 45,585 | 52,476 | 73,012 | 107.5% |
| | Allendale (SC) | 5,399 | 4,581 | 4,273 | 4,128 | 4,784 | -11.4% |
| | Bamberg (SC) | 6,327 | 6,268 | 6,691 | 6,118 | 6,139 | -3.0% |
| | Barnwell (SC) | 7,598 | 8,827 | 8,942 | 9,766 | 9,242 | 21.6% |
| | Burke (GA) | 5,833 | 6,457 | 7,806 | 16,144 | 8,470 | 45.2% |
| | Columbia (GA) | 21,949 | 15,829 | 22,958 | 26,033 | 28,284 | 28.9% |
| | Richmond (GA) | 71,085 | 79,213 | 90,877 | 102,953 | 119,064 | 67.5% |
| | Screven (GA) | 4,752 | 5,392 | 5,906 | 5,587 | 5,782 | 21.7% |
| | | 158,124 | 165,154 | 193,038 | 223,205 | 254,777 | 61.1% |
| SLAC | Alameda (CA) | 490,578 | 509,946 | 588,728 | 656,286 | 738,160 | 50.5% |
| | Monterey (CA) | 131,810 | 147,482 | 156,959 | 176,632 | 202,533 | 53.7% |
| | San Benito (CA) | 7,902 | 9,020 | 10,481 | 11,808 | 15,212 | 92.5% |
| | San Mateo (CA) | 227,090 | 259,528 | 313,958 | 349,819 | 396,533 | 74.6% |
| | Santa Clara (CA) | 446,473 | 553,366 | 790,461 | 930,931 | 1,015,759 | 127.5% |
| | Santa Cruz (CA) | 47,367 | 61,480 | 82,228 | 102,096 | 122,735 | 159.1% |
| | Stanislaus (CA) | 81,872 | 98,597 | 121,735 | 132,122 | 166,656 | 103.6% |
| | | 1,433,092 | 1,639,419 | 2,064,550 | 2,359,694 | 2,657,588 | 85.4% |
| U of Mo | Audrain (MO) | 12,400 | 12,868 | 13,518 | 12,386 | 12,779 | 3.1% |
| | Boone (MO) | 39,057 | 46,023 | 56,810 | 63,584 | 75,366 | 93.0% |
| | Callaway (MO) | 10,588 | 11,120 | 16,920 | 14,611 | 16,281 | 53.8% |
| | Cole (MO) | 28,045 | 32,876 | 38,421 | 42,868 | 48,500 | 72.9% |
| | Cooper (MO) | 6,488 | 6,913 | 6,965 | 7,026 | 7,097 | 9.4% |
| | Howard (MO) | 4,866 | 4,555 | 4,190 | 4,364 | 4,421 | -9.1% |
| | Moniteau (MO) | 4,796 | 4,722 | 5,338 | 5,752 | 6,231 | 29.9% |
| | Randolph (MO) | 8,977 | 9,883 | 11,321 | 12,350 | 12,666 | 41.1% |
| | | 115,217 | 128,960 | 153,483 | 162,941 | 183,341 | 59.1% |
| WIPP | Chaves (NM) | 16,649 | 19,528 | 22,695 | 25,116 | 26,216 | 57.5% |
| | Eddy (NM) | 15,825 | 18,410 | 21,374 | 22,298 | 21,748 | 37.4% |
| | Lea (NM) | 20,607 | 23,894 | 29,280 | 30,095 | 25,009 | 21.4% |
| | Otero (NM) | 19,079 | 20,526 | 22,626 | 25,681 | 24,956 | 30.8% |
| | Culberson (TX) | 1,854 | 1,848 | 1,897 | 1,815 | 1,718 | -7.3% |
| | Loving (TX) | 102 | 175 | 131 | 123 | 60 | -41.2% |
| | | 74,116 | 84,381 | 98,003 | 105,128 | 99,707 | 34.5% |
| WSSR | Franklin (MO) | 19,479 | 22,207 | 27,656 | 31,825 | 38,233 | 96.3% |
| | Jefferson (MO) | 19,773 | 21,857 | 29,787 | 38,875 | 47,635 | 140.9% |
| | St. Charles (MO) | 23,441 | 29,902 | 40,985 | 66,107 | 83,286 | 255.3% |
| | St. Louis (MO) | 355,947 | 393,919 | 477,764 | 610,547 | 695,600 | 95.4% |
| | Madison (IL) | 97,430 | 96,639 | 100,691 | 99,640 | 112,247 | 15.2% |
| | Monroe (IL) | 4,923 | 5,464 | 5,742 | 6,598 | 7,448 | 51.3% |
| | St. Clair (IL) | 91,681 | 94,622 | 99,354 | 98,863 | 105,059 | 14.6% |
| | | 612,674 | 664,610 | 781,979 | 952,455 | 1,089,508 | 77.8% |

***Table C.4–18. Baseline Employment Data—Continued***

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| WVDP | Cattaraugus (NY) | 31,724 | 32,991 | 35,540 | 35,920 | 39,434 | 24.3% |
| | Erie (NY) | 465,799 | 466,761 | 477,986 | 476,411 | 529,812 | 13.7% |
| | | 497,523 | 499,752 | 513,526 | 512,331 | 569,246 | 14.4% |
| UNITED STATES | | 89,753 | 97,177 | 112,257 | 123,176 | 137,160 | 52.8% |

Notes: Ames = Ames Laboratory; ANL-E = Argonne National Laboratory-East; Bettis = Bettis Atomic Power Plant; BCL = Battelle Columbus Laboratories; BNL = Brookhaven National Laboratory; Charleston = Charleston Naval Shipyard; ETEC = Energy Technology Engineering Center; FEMP = Fernald Environmental Management Project; Fermi = Fermi National Accelerator Laboratory; GE = General Electric Vallecitos Nuclear Center; INEL = Idaho National Engineering Laboratory; KAPL-N = Knolls Atomic Power Laboratory (Niskayuna); LLNL = Lawrence Livermore National Laboratory; LANL = Los Alamos National Laboratory; GA = General Atomics; GJPO = Grand Junction Projects Office; KAPL-K = Knolls Atomic Power Laboratory (Kesselring); KAPL-W = Knolls Atomic Power Laboratory (Windsor); KCP = Kansas City Plant; LBL = Lawrence Berkeley National Laboratory; LEHR = Laboratory for Energy-Related Health Research; Mare Is = Mare Island Naval Shipyard; Middlesex = Middlesex Sampling Laboratory; Mound = Mound Plant; Norfolk = Norfolk Naval Shipyard; NTS = Nevada Test Site; ORR = Oak Ridge Reservation; Palos = Palos Forest; Pearl H = Pearl Harbor Naval Shipyard; PGDP = Paducah Gaseous Diffusion Plant; PORTS = Portsmouth Gaseous Diffusion Plant; Ports Nav = Portsmouth Naval Shipyard; PPPL = Princeton Plasma Physics Laboratory; Puget So = Puget Sound Naval Shipyard; RFETS = Rocky Flats Environmental Technology Site; RMI = Reactive Metals, Inc.; SLAC = Stanford Linear Accelerator System; SNL/NM = Sandia National Laboratories (New Mexico); SRS = Savannah River Site; UofMO = University of Missouri; WIPP = Waste Isolation Pilot Plant; WSSR = Weldon Spring Site Remedial Action Project; and WVDP = West Valley Demonstration Project.

Source: U.S. Department of Commerce (1992a).

## C.4.5.3 Impacts Analysis Procedures

### C.4.5.3.1 *Development of Regional Multipliers*

The economic impact analysis was conducted by first determining how responsive the National economy and the various regional economies were to a change in expenditures. The result of this determination was quantified in what is termed a "multiplier." Each site has a unique ROI (relevant counties as defined below) and each industry within that region has a unique degree of responsiveness to changes in the level of expenditures in the region. Multipliers for disposable income, output, and job-years were developed for 80 industries (industrial sectors) for the aggregate county regions of influence and the national economy. The multipliers were derived from an 80-sector model based on the Regional Input-Output Modeling System (RIMS II) approach developed by the U.S. Department of Commerce, Bureau of Economic Analysis (DOC, 1992b).

The procedure for developing the regional multipliers required establishing an economic ROI for each site. This was done by identifying those counties in the vicinity of the site where economic impacts would be expected to occur. Counties are unique in their ability to provide the labor and other resources necessary to any particular line of production. The demand for intermediate goods (i.e., goods that are used in the production of other goods) is a function of the demand for final goods. The technique used to measure a county's ability to satisfy production requirements was first to establish the relationships between industries

## Table C.4-19. Baseline Personal Income

Total Personal Income ($ million)

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| Ames | Boone (IA) | 98.6 | 168.7 | 261.4 | 324.0 | 402.3 | 308.1% |
| | Hamilton (IA) | 74.5 | 128.7 | 190.3 | 246.3 | 314.7 | 322.6% |
| | Hardin (IA) | 92.0 | 141.9 | 215.9 | 276.2 | 333.6 | 262.7% |
| | Jasper (IA) | 142.1 | 228.1 | 356.8 | 485.9 | 634.1 | 346.2% |
| | Marshall (IA) | 182.4 | 290.9 | 433.1 | 539.1 | 692.8 | 279.8% |
| | Polk (IA) | 1,268.0 | 2,073.2 | 3,444.2 | 4,703.3 | 6,620.9 | 422.1% |
| | Story (IA) | 210.3 | 354.0 | 633.2 | 879.5 | 1,180.8 | 461.6% |
| | | 2,067.9 | 3,385.5 | 5,534.9 | 7,454.2 | 10,179.3 | 392.3% |
| ANL-E | Cook (IL) | 27,609.0 | 39,409.7 | 60,465.2 | 82,068.1 | 110,927.8 | 301.8% |
| | Du Page (IL) | 2,611.0 | 4,636.8 | 9,007.3 | 13,480.1 | 21,043.2 | 706.0% |
| | Kane (IL) | 1,169.8 | 1,863.4 | 3,117.7 | 4,490.1 | 6,914.2 | 491.0% |
| | Will (IL) | 1,068.0 | 1,844.2 | 3,372.3 | 4,633.2 | 6,738.2 | 530.9% |
| | | 32,457.8 | 47,754.1 | 75,962.5 | 104,671.5 | 145,623.4 | 348.7% |
| BCL | Delaware (OH) | 159.0 | 281.1 | 510.6 | 799.7 | 1,279.4 | 704.5% |
| | Fairfield (OH) | 263.5 | 456.6 | 848.7 | 1,219.1 | 1,697.2 | 544.1% |
| | Franklin (OH) | 3,449.1 | 5,284.4 | 8,639.7 | 12,854.9 | 18,376.0 | 432.8% |
| | Licking (OH) | 374.3 | 617.4 | 1,088.2 | 1,566.7 | 2,109.6 | 463.6% |
| | Madison (OH) | 100.3 | 169.6 | 275.1 | 385.7 | 580.5 | 478.6% |
| | Pickaway (OH) | 135.1 | 221.6 | 354.5 | 488.5 | 666.3 | 393.2% |
| | Union (OH) | 89.0 | 155.0 | 267.8 | 384.4 | 618.8 | 595.2% |
| | | 4,570.4 | 7,185.5 | 11,984.7 | 17,698.9 | 25,327.8 | 454.2% |
| Bettis | Allegheny (PA) | 7,024.7 | 10,277.7 | 16,072.4 | 20,701.8 | 27,600.6 | 292.9% |
| | Armstrong (PA) | 243.3 | 415.6 | 691.0 | 929.1 | 1,228.3 | 404.8% |
| | Beaver (PA) | 742.2 | 1,236.9 | 2,061.3 | 2,261.5 | 2,816.5 | 279.5% |
| | Butler (PA) | 474.9 | 785.4 | 1,384.4 | 1,834.4 | 2,626.3 | 453.0% |
| | Washington (PA) | 759.5 | 1,246.5 | 2,066.4 | 2,584.4 | 3,396.7 | 347.2% |
| | Westmoreland (PA) | 1,383.8 | 2,153.6 | 3,803.4 | 4,816.0 | 6,316.2 | 356.4% |
| | | 10,628.3 | 16,115.6 | 26,078.8 | 33,127.3 | 43,984.7 | 313.8% |
| BNL | Nassau (NY) | 8,524.6 | 11,845.3 | 18,941.6 | 28,244.9 | 40,745.2 | 378.0% |
| | Suffolk (NY) | 4,876.5 | 7,924.0 | 13,650.9 | 21,596.1 | 32,091.6 | 558.1% |
| | | 13,401.1 | 19,769.3 | 32,592.5 | 49,840.9 | 72,836.8 | 443.5% |
| Charleston | Berkeley (SC) | 145.2 | 301.4 | 635.6 | 1,116.0 | 1,672.5 | 1051.5% |
| | Charleston (SC) | 835.3 | 1,363.4 | 2,236.8 | 3,280.0 | 4,741.6 | 467.6% |
| | Colleton (SC) | 65.6 | 110.9 | 196.7 | 282.0 | 407.9 | 521.6% |
| | Dorchester (SC) | 95.5 | 201.6 | 461.7 | 769.4 | 1,175.2 | 1130.0% |
| | | 1,141.7 | 1,977.4 | 3,530.8 | 5,447.5 | 7,997.2 | 600.4% |
| Colonie | Albany (NY) | 1,378.0 | 2,028.6 | 3,027.7 | 4,382.5 | 6,147.6 | 346.1% |
| | Columbia (NY) | 194.8 | 325.4 | 564.1 | 846.2 | 1,239.0 | 536.0% |
| | Greene (NY) | 123.8 | 204.4 | 341.3 | 496.2 | 735.9 | 494.4% |
| | Rensselaer (NY) | 574.8 | 827.5 | 1,306.1 | 1,907.1 | 2,745.3 | 377.7% |
| | Saratoga (NY) | 437.1 | 738.5 | 1,374.4 | 2,153.7 | 3,435.4 | 686.0% |
| | Schenectady (NY) | 738.5 | 1,025.3 | 1,544.5 | 2,243.2 | 3,086.2 | 317.9% |
| | Schoharie (NY) | 85.1 | 131.6 | 210.6 | 302.6 | 455.6 | 435.6% |
| | | 3,532.0 | 5,281.4 | 8,368.7 | 12,331.4 | 17,845.0 | 405.2% |
| ETEC | Kern (CA) | 1,267.9 | 2,189.1 | 4,321.3 | 6,224.1 | 8,691.4 | 585.5% |
| | Los Angeles (CA) | 35,043.2 | 50,436.0 | 88,053.0 | 130,394.8 | 185,131.4 | 428.3% |
| | San Luis Obispo (CA) | 388.3 | 718.0 | 1,443.5 | 2,469.8 | 3,767.8 | 870.3% |
| | Santa Barbara (CA) | 1,235.4 | 1,949.3 | 3,563.0 | 5,696.0 | 8,134.3 | 558.4% |
| | Ventura (CA) | 1,589.4 | 2,901.8 | 5,940.7 | 9,495.6 | 14,428.4 | 807.8% |
| | | 39,524.2 | 58,194.3 | 103,321.5 | 154,280.3 | 220,153.3 | 457.0% |

## *Table C.4–19. Baseline Personal Income—Continued*

Total Personal Income ($ million)

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| Fermi | Cook (IL) | 27,609.0 | 39,409.7 | 60,465.2 | 82,068.1 | 110,927.8 | 301.8% |
| | De Kalb (IL) | 264.8 | 431.7 | 675.2 | 935.5 | 1,286.3 | 385.8% |
| | Du Page (IL) | 2,611.0 | 4,636.8 | 9,007.3 | 13,480.1 | 21,043.2 | 706.0% |
| | Kane (IL) | 1,169.8 | 1,863.4 | 3,117.7 | 4,490.1 | 6,914.2 | 491.0% |
| | Kendall (IL) | 122.6 | 226.6 | 425.2 | 549.7 | 797.7 | 550.6% |
| | McHenry (IL) | 519.0 | 895.6 | 1,677.4 | 2,509.2 | 4,032.9 | 677.1% |
| | Will (IL) | 1,068.0 | 1,844.2 | 3,372.3 | 4,633.2 | 6,738.2 | 530.9% |
| | | 33,364.2 | 49,307.9 | 78,740.3 | 108,665.9 | 151,740.3 | 354.8% |
| FEMP | Butler (OH) | 870.5 | 1,386.6 | 2,508.2 | 3,473.1 | 4,902.0 | 463.1% |
| | Hamilton (OH) | 4,130.7 | 5,879.9 | 9,405.5 | 12,973.0 | 17,837.8 | 331.8% |
| | Warren (OH) | 302.0 | 476.2 | 890.9 | 1,271.3 | 1,973.6 | 553.6% |
| | Dearborn (IN) | 101.0 | 162.8 | 295.4 | 430.2 | 594.3 | 488.4% |
| | | 5,404.2 | 7,905.5 | 13,099.9 | 18,147.7 | 25,307.8 | 368.3% |
| GA | Imperial (CA) | 299.6 | 527.9 | 888.2 | 1,085.6 | 1,595.3 | 432.4% |
| | Orange (CA) | 7,013.6 | 12,242.3 | 25,407.5 | 40,169.6 | 59,190.7 | 743.9% |
| | Riverside (CA) | 2,012.5 | 3,522.1 | 7,104.1 | 11,674.0 | 20,431.5 | 915.2% |
| | San Diego (CA) | 6,163.1 | 10,294.5 | 19,917.7 | 32,190.3 | 49,344.3 | 700.6% |
| | | 15,488.9 | 26,586.7 | 53,317.4 | 85,119.4 | 130,561.8 | 742.9% |
| GE | Alpine (CA) | 2.1 | 4.1 | 9.2 | 15.4 | 25.5 | 1093.0% |
| | Amador (CA) | 49.0 | 89.4 | 188.3 | 292.7 | 456.0 | 830.6% |
| | Calaveras (CA) | 51.6 | 86.1 | 184.4 | 294.0 | 442.3 | 757.8% |
| | San Joaquin (CA) | 1,215.3 | 2,033.7 | 3,634.5 | 5,215.1 | 7,484.0 | 515.8% |
| | Stanislaus (CA) | 766.1 | 1,335.7 | 2,577.1 | 3,743.3 | 5,699.3 | 644.0% |
| | Tuolumne (CA) | 81.5 | 144.9 | 308.1 | 481.9 | 724.9 | 789.9% |
| | | 2,165.5 | 3,693.8 | 6,901.6 | 10,042.2 | 14,832.0 | 584.9% |
| GJPO | Delta (CO) | 45.8 | 84.7 | 168.8 | 229.5 | 278.8 | 508.9% |
| | Garfield (CO) | 56.6 | 115.9 | 236.2 | 335.4 | 486.7 | 759.5% |
| | Gunnison (CO) | 18.1 | 36.2 | 80.5 | 109.7 | 139.9 | 674.4% |
| | Mesa (CO) | 183.4 | 365.3 | 805.0 | 1,041.8 | 1,412.7 | 670.2% |
| | Montrose (CO) | 53.3 | 97.5 | 186.2 | 253.7 | 350.9 | 558.6% |
| | Pitkin (CO) | 36.0 | 79.9 | 169.4 | 249.0 | 412.7 | 1047.6% |
| | Grand (UT) | 23.1 | 37.5 | 77.9 | 76.8 | 88.0 | 280.6% |
| | | 416.3 | 817.0 | 1,724.1 | 2,295.8 | 3,169.8 | 661.5% |
| Hanford | Adams (WA) | 54.7 | 122.5 | 146.2 | 184.3 | 230.7 | 321.6% |
| | Benton (WA) | 269.5 | 536.2 | 1,200.8 | 1,473.4 | 1,959.2 | 626.9% |
| | Franklin (WA) | 98.0 | 197.9 | 358.6 | 409.2 | 553.1 | 464.6% |
| | Grant (WA) | 148.4 | 296.4 | 444.2 | 601.8 | 853.8 | 475.2% |
| | Yakima (WA) | 496.0 | 929.0 | 1,549.3 | 2,046.8 | 2,920.4 | 488.8% |
| | | 1,066.7 | 2,082.0 | 3,699.2 | 4,715.4 | 6,517.2 | 511.0% |
| INEL | Bannock (ID) | 169.4 | 310.5 | 554.3 | 731.3 | 884.6 | 422.1% |
| | Bingham (ID) | 93.5 | 161.6 | 266.2 | 353.4 | 512.5 | 448.0% |
| | Bonneville (ID) | 189.5 | 339.7 | 588.5 | 837.4 | 1,203.7 | 535.2% |
| | Butte (ID) | 9.5 | 14.0 | 28.2 | 32.2 | 45.8 | 380.6% |
| | Clark (ID) | 4.7 | 6.1 | 10.1 | 12.7 | 20.2 | 327.9% |
| | Jefferson (ID) | 34.6 | 61.4 | 106.7 | 136.6 | 212.2 | 512.8% |
| | | 501.3 | 893.2 | 1,554.0 | 2,103.7 | 2,879.0 | 474.3% |
| KCP | Cass (MO) | 132.6 | 250.9 | 484.7 | 753.2 | 1,092.3 | 724.1% |
| | Clay (MO) | 501.9 | 784.7 | 1,467.5 | 2,172.1 | 2,833.8 | 464.6% |
| | Jackson (MO) | 2,825.6 | 4,181.1 | 6,531.9 | 9,141.2 | 11,798.7 | 317.6% |
| | Johnson (MO) | 104.7 | 160.3 | 261.7 | 381.3 | 521.4 | 397.9% |
| | Lafayette (MO) | 103.7 | 161.5 | 264.7 | 381.7 | 504.7 | 386.6% |
| | Ray (MO) | 61.0 | 102.1 | 187.6 | 271.4 | 335.7 | 450.4% |
| | Johnson (KS) | 1,151.1 | 1,940.2 | 3,776.0 | 5,973.0 | 9,355.4 | 712.7% |
| | Wyandotte (KS) | 650.3 | 944.2 | 1,479.1 | 1,941.4 | 2,284.9 | 251.4% |
| | | 5,530.9 | 8,525.0 | 14,453.1 | 21,015.4 | 28,726.9 | 419.4% |

## Table C.4-19. Baseline Personal Income—Continued

Total Personal Income ($ million)

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| KAPL-K | Fulton (NY) | 189.8 | 279.0 | 448.1 | 619.9 | 849.2 | 347.5% |
| | Saratoga (NY) | 437.1 | 738.5 | 1,374.4 | 2,153.7 | 3,435.4 | 686.0% |
| | Schenectady (NY) | 738.5 | 1,025.3 | 1,544.5 | 2,243.2 | 3,086.2 | 317.9% |
| | | 1,365.4 | 2,042.7 | 3,367.0 | 5,016.7 | 7,370.7 | 439.8% |
| KAPL-N | Albany (NY) | 1,378.0 | 2,028.6 | 3,027.7 | 4,382.5 | 6,147.6 | 346.1% |
| | Montgomery (NY) | 210.7 | 290.7 | 446.5 | 599.3 | 835.0 | 296.4% |
| | Saratoga (NY) | 437.1 | 738.5 | 1,374.4 | 2,153.7 | 3,435.4 | 686.0% |
| | Schenectady (NY) | 738.5 | 1,025.3 | 1,544.5 | 2,243.2 | 3,086.2 | 317.9% |
| | Schoharie (NY) | 85.1 | 131.6 | 210.6 | 302.6 | 455.6 | 435.6% |
| | | 2,849.3 | 4,214.7 | 6,603.7 | 9,681.2 | 13,959.8 | 389.9% |
| KAPL-W | Hartford (CT) | 4,109.6 | 5,812.0 | 9,720.2 | 14,610.2 | 21,209.3 | 416.1% |
| | Litchfield (CT) | 689.5 | 1,053.0 | 1,876.1 | 2,905.6 | 4,391.3 | 536.9% |
| | Middlesex (CT) | 535.9 | 837.8 | 1,452.3 | 2,279.9 | 3,462.3 | 546.0% |
| | New Haven (CT) | 3,509.0 | 5,060.5 | 8,305.2 | 12,501.4 | 17,872.5 | 409.3% |
| | Tolland (CT) | 412.0 | 622.6 | 1,167.7 | 1,826.0 | 2,831.8 | 587.3% |
| | Hampden (MA) | 1,866.9 | 2,696.5 | 4,323.7 | 6,220.6 | 8,706.2 | 366.4% |
| | | 11,122.9 | 16,082.3 | 26,845.1 | 40,343.8 | 58,473.4 | 425.7% |
| LEHR | Colusa (CA) | 73.5 | 143.5 | 178.3 | 205.3 | 278.4 | 278.7% |
| | Lake (CA) | 77.1 | 150.6 | 349.4 | 559.9 | 789.4 | 924.2% |
| | Napa (CA) | 362.2 | 638.6 | 1,145.6 | 1,712.0 | 2,519.8 | 595.8% |
| | Sacramento (CA) | 2,766.4 | 4,513.4 | 8,310.2 | 12,912.8 | 19,873.9 | 618.4% |
| | Solano (CA) | 695.7 | 1,252.9 | 2,402.7 | 3,749.2 | 5,935.3 | 753.2% |
| | Sutter (CA) | 187.1 | 346.9 | 557.4 | 743.3 | 1,032.1 | 451.7% |
| | Yolo (CA) | 407.3 | 734.0 | 1,239.1 | 1,775.7 | 2,801.9 | 588.0% |
| | | 4,569.1 | 7,779.8 | 14,182.8 | 21,658.2 | 33,230.9 | 627.3% |
| LBL | Alameda (CA) | 5,187.3 | 7,674.5 | 13,092.7 | 20,275.5 | 28,453.8 | 448.5% |
| | Contra Costa (CA) | 2,774.2 | 4,452.6 | 8,785.0 | 13,924.1 | 20,647.5 | 644.3% |
| | | 7,961.5 | 12,127.2 | 21,877.7 | 34,199.6 | 49,101.3 | 516.7% |
| LLNL | Alameda (CA) | 5,187.3 | 7,674.5 | 13,092.7 | 20,275.5 | 28,453.8 | 448.5% |
| | Contra Costa (CA) | 2,774.2 | 4,452.6 | 8,785.0 | 13,924.1 | 20,647.5 | 644.3% |
| | San Joaquin (CA) | 1,215.3 | 2,033.7 | 3,634.5 | 5,215.1 | 7,484.0 | 515.8% |
| | Stanislaus (CA) | 766.1 | 1,335.7 | 2,577.1 | 3,743.3 | 5,699.3 | 644.0% |
| | | 9,942.9 | 15,496.5 | 28,089.2 | 43,157.9 | 62,284.6 | 526.4% |
| LANL | Los Alamos (NM) | 78.1 | 124.7 | 221.4 | 364.4 | 505.8 | 547.8% |
| | Rio Arriba (NM) | 53.8 | 92.1 | 163.6 | 240.3 | 312.1 | 480.0% |
| | Santa Fe (NM) | 192.8 | 352.3 | 677.2 | 1,140.1 | 1,704.0 | 784.0% |
| | | 324.7 | 569.1 | 1,062.1 | 1,744.8 | 2,521.9 | 676.8% |
| Mare Is | Contra Costa (CA) | 2,774.2 | 4,452.6 | 8,785.0 | 13,924.1 | 20,647.5 | 644.3% |
| | Lake (CA) | 77.1 | 150.6 | 349.4 | 559.9 | 789.4 | 924.2% |
| | Marin (CA) | 1,229.1 | 1,945.1 | 3,813.8 | 6,056.3 | 8,657.2 | 604.3% |
| | Mendocino (CA) | 195.4 | 329.5 | 650.2 | 900.8 | 1,301.1 | 565.8% |
| | Napa (CA) | 362.2 | 638.6 | 1,145.6 | 1,712.0 | 2,519.8 | 595.8% |
| | Sonoma (CA) | 921.5 | 1,694.7 | 3,430.8 | 5,556.0 | 8,628.9 | 836.4% |
| | | 5,559.5 | 9,211.0 | 18,174.8 | 28,709.0 | 42,543.9 | 665.3% |
| Middlesex | Mercer (NJ) | 1,475.4 | 2,314.5 | 3,647.9 | 5,707.3 | 8,491.9 | 475.6% |
| | Middlesex (NJ) | 2,751.4 | 4,303.7 | 7,057.0 | 11,558.7 | 16,761.1 | 509.2% |
| | Monmouth (NJ) | 2,120.8 | 3,380.2 | 6,038.3 | 10,105.8 | 15,178.4 | 615.7% |
| | Somerset (NJ) | 1,055.7 | 1,604.0 | 2,919.1 | 4,991.5 | 8,009.3 | 658.7% |
| | Union (NJ) | 3,002.8 | 4,035.9 | 6,505.8 | 9,621.6 | 12,943.0 | 331.0% |
| | | 10,406.1 | 15,638.3 | 26,168.1 | 41,984.8 | 61,383.7 | 489.9% |

## *Table C.4–19. Baseline Personal Income—Continued*

Total Personal Income ($ million)

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| Mound | Butler (OH) | 870.5 | 1,386.6 | 2,508.2 | 3,473.1 | 4,902.0 | 463.1% |
| | Clark (OH) | 588.0 | 853.4 | 1,331.4 | 1,832.4 | 2,461.8 | 318.7% |
| | Darke (OH) | 175.2 | 277.8 | 463.8 | 641.3 | 864.6 | 393.4% |
| | Greene (OH) | 502.0 | 750.2 | 1,243.6 | 1,742.3 | 2,490.0 | 396.0% |
| | Miami (OH) | 337.8 | 502.0 | 860.2 | 1,171.6 | 1,585.3 | 369.3% |
| | Montgomery (OH) | 2,630.1 | 3,625.9 | 5,742.2 | 7,999.6 | 10,577.1 | 302.2% |
| | Preble (OH) | 123.9 | 188.0 | 320.9 | 444.0 | 598.6 | 383.0% |
| | Warren (OH) | 302.0 | 476.2 | 890.9 | 1,271.3 | 1,973.6 | 553.6% |
| | | 5,529.5 | 8,060.0 | 13,361.3 | 18,575.6 | 25,453.1 | 360.3% |
| NTS | Clark (NV) | 1,335.2 | 2,337.6 | 5,123.0 | 7,843.2 | 14,087.5 | 955.1% |
| | Nye (NV) | 27.6 | 44.6 | 100.3 | 167.9 | 273.9 | 892.9% |
| | | 1,362.8 | 2,382.2 | 5,223.3 | 8,011.0 | 14,361.4 | 953.8% |
| Norfolk | Chesapeake city (VA) | 296.6 | 537.7 | 1,025.5 | 1,672.3 | 2,593.7 | 774.4% |
| | Hampton city (VA) | 420.2 | 648.9 | 1,006.2 | 1,513.1 | 1,979.0 | 371.0% |
| | Newport News city (VA) | 490.8 | 753.8 | 1,281.5 | 1,985.1 | 2,613.3 | 432.5% |
| | Norfolk city (VA) | 1,111.8 | 1,610.3 | 2,339.9 | 3,389.0 | 4,280.1 | 285.0% |
| | Suffolk city (VA) | 139.3 | 244.5 | 407.5 | 635.0 | 878.2 | 530.3% |
| | Virginia Beach city (VA) | 690.0 | 1,354.7 | 2,707.1 | 4,745.4 | 7,024.8 | 918.0% |
| | Isle of Wight (VA) | 57.0 | 105.1 | 191.2 | 313.7 | 451.6 | 692.2% |
| | | 3,205.7 | 5,255.0 | 8,958.9 | 14,253.5 | 19,820.6 | 518.3% |
| ORR | Anderson (TN) | 203.2 | 346.8 | 586.1 | 801.7 | 1,121.1 | 451.6% |
| | Knox (TN) | 923.2 | 1,562.5 | 2,788.6 | 4,045.7 | 5,844.4 | 533.1% |
| | Loudon (TN) | 66.9 | 117.2 | 218.8 | 293.0 | 433.5 | 547.5% |
| | Roane (TN) | 110.5 | 199.2 | 395.6 | 527.8 | 727.5 | 558.2% |
| | | 1,303.9 | 2,225.7 | 3,989.2 | 5,668.2 | 8,126.4 | 523.2% |
| PGDP | Ballard (KY) | 27.8 | 41.9 | 70.6 | 88.7 | 122.9 | 342.3% |
| | Carlisle (KY) | 13.9 | 22.9 | 37.5 | 52.9 | 66.1 | 374.1% |
| | Graves (KY) | 93.0 | 150.4 | 266.5 | 355.9 | 482.0 | 418.4% |
| | Marshall (KY) | 61.7 | 107.4 | 215.1 | 287.2 | 398.7 | 545.8% |
| | McCracken (KY) | 209.4 | 335.7 | 588.6 | 777.3 | 1,099.4 | 425.1% |
| | Massac (IL) | 41.4 | 71.8 | 113.5 | 151.3 | 195.3 | 372.3% |
| | | 447.2 | 730.2 | 1,291.8 | 1,713.3 | 2,364.5 | 428.8% |
| Palos | Cook (IL) | 27,609.0 | 39,409.7 | 60,465.2 | 82,068.1 | 110,927.8 | 301.8% |
| | Du Page (IL) | 2,611.0 | 4,636.8 | 9,007.3 | 13,480.1 | 21,043.2 | 706.0% |
| | Kane (IL) | 1,169.8 | 1,863.4 | 3,117.7 | 4,490.1 | 6,914.2 | 491.0% |
| | Lake (IL) | 1,980.9 | 3,214.4 | 5,837.8 | 8,946.3 | 14,211.2 | 617.4% |
| | McHenry (IL) | 519.0 | 895.6 | 1,677.4 | 2,509.2 | 4,032.9 | 677.1% |
| | Will (IL) | 1,068.0 | 1,844.2 | 3,372.3 | 4,633.2 | 6,738.2 | 530.9% |
| | Lake (IN) | 2,159.4 | 3,257.7 | 5,187.4 | 5,916.4 | 7,758.7 | 259.3% |
| | | 37,117.1 | 55,121.9 | 88,665.1 | 122,043.4 | 171,626.2 | 362.4% |
| Pantex | Carson (TX) | 27.2 | 67.5 | 63.0 | 99.1 | 117.7 | 332.1% |
| | Potter (TX) | 315.2 | 512.3 | 958.9 | 1,357.7 | 1,589.1 | 404.1% |
| | Randall (TX) | 233.3 | 448.3 | 768.8 | 1,295.3 | 1,598.0 | 585.0% |
| | | 575.7 | 1,028.2 | 1,790.7 | 2,752.0 | 3,304.7 | 474.0% |
| Pearl H | Honolulu (HI) | 3,194.4 | 5,090.3 | 8,293.1 | 11,815.8 | 17,880.7 | 459.8% |
| | Kauai (HI) | 121.2 | 207.8 | 374.4 | 515.8 | 884.1 | 629.5% |
| | Maui (HI) | 193.9 | 371.9 | 710.5 | 1,068.6 | 1,876.8 | 867.7% |
| | | 3,509.5 | 5,670.1 | 9,377.9 | 13,400.2 | 20,641.6 | 488.2% |
| Pinellas | Hillsborough (FL) | 1,683.7 | 3,130.5 | 5,593.9 | 9,497.0 | 14,177.8 | 742.1% |
| | Pasco (FL) | 249.7 | 650.0 | 1,562.5 | 2,703.0 | 3,960.7 | 1486.4% |
| | Pinellas (FL) | 2,189.0 | 4,014.7 | 7,710.5 | 12,857.5 | 18,483.7 | 744.4% |
| | | 4,122.3 | 7,795.2 | 14,866.9 | 25,057.5 | 36,622.1 | 788.4% |

## Table C.4-19. Baseline Personal Income—Continued

Total Personal Income ($ million)

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| PORTS | Jackson (OH) | 72.1 | 119.0 | 201.6 | 279.2 | 347.6 | 382.2% |
| | Pike (OH) | 48.3 | 81.3 | 146.2 | 219.3 | 291.7 | 503.6% |
| | Ross (OH) | 194.9 | 300.8 | 529.4 | 737.0 | 935.8 | 380.1% |
| | Scioto (OH) | 247.0 | 364.1 | 608.4 | 788.9 | 1,017.3 | 311.9% |
| | | 562.3 | 865.1 | 1,485.6 | 2,024.4 | 2,592.4 | 361.0% |
| Ports Nav | Cumberland (ME) | 766.5 | 1,192.3 | 2,041.5 | 3,270.8 | 5,211.5 | 579.9% |
| | Oxford (ME) | 139.9 | 216.5 | 391.7 | 528.2 | 786.0 | 462.0% |
| | York (ME) | 399.4 | 629.7 | 1,187.1 | 1,896.6 | 2,960.5 | 641.2% |
| | Carroll (NH) | 73.7 | 134.3 | 267.1 | 461.5 | 780.8 | 959.5% |
| | Rockingham (NH) | 536.8 | 904.9 | 1,957.5 | 3,566.5 | 5,369.4 | 900.3% |
| | Strafford (NH) | 245.0 | 368.3 | 735.1 | 1,195.7 | 1,794.5 | 632.5% |
| | | 2,161.3 | 3,446.0 | 6,580.0 | 10,919.3 | 16,902.6 | 682.1% |
| PPPL | Burlington (NJ) | 1,326.0 | 2,172.7 | 3,897.1 | 6,067.2 | 9,106.0 | 586.7% |
| | Hunterdon (NJ) | 344.2 | 600.8 | 1,139.9 | 2,043.2 | 3,276.3 | 852.0% |
| | Mercer (NJ) | 1,475.4 | 2,314.5 | 3,647.9 | 5,707.3 | 8,491.9 | 475.6% |
| | Middlesex (NJ) | 2,751.4 | 4,303.7 | 7,057.0 | 11,558.7 | 16,761.1 | 509.2% |
| | Monmouth (NJ) | 2,120.8 | 3,380.2 | 6,038.3 | 10,105.8 | 15,178.4 | 615.7% |
| | Somerset (NJ) | 1,055.7 | 1,604.0 | 2,919.1 | 4,991.5 | 8,009.3 | 658.7% |
| | Bucks (PA) | 1,754.2 | 2,875.8 | 5,280.3 | 8,132.8 | 12,250.6 | 598.3% |
| | | 10,827.6 | 17,251.7 | 29,979.6 | 48,606.4 | 73,073.7 | 574.9% |
| Puget So | Jefferson (WA) | 39.3 | 71.1 | 156.3 | 226.7 | 329.2 | 738.1% |
| | King (WA) | 5,583.1 | 8,507.6 | 16,470.2 | 23,445.3 | 36,181.4 | 548.1% |
| | Kitsap (WA) | 430.4 | 761.3 | 1,485.0 | 2,232.2 | 3,262.1 | 657.9% |
| | Mason (WA) | 75.2 | 135.1 | 279.3 | 390.6 | 547.2 | 628.0% |
| | Pierce (WA) | 1,654.8 | 2,561.0 | 4,738.9 | 6,764.8 | 9,583.1 | 479.1% |
| | | 7,782.8 | 12,036.2 | 23,129.8 | 33,059.5 | 49,903.0 | 541.2% |
| RMI | Ashtabula (OH) | 347.8 | 526.1 | 875.2 | 1,102.7 | 1,337.9 | 284.7% |
| | Geauga (OH) | 256.8 | 415.1 | 826.7 | 1,164.4 | 1,688.0 | 557.4% |
| | Lake (OH) | 823.6 | 1,276.0 | 2,270.5 | 3,096.8 | 4,249.0 | 415.9% |
| | Trumbull (OH) | 935.6 | 1,494.9 | 2,400.7 | 2,937.9 | 3,673.6 | 292.7% |
| | Crawford (PA) | 281.0 | 443.6 | 715.2 | 937.7 | 1,241.6 | 341.8% |
| | Erie (PA) | 1,015.4 | 1,623.4 | 2,544.8 | 3,358.2 | 4,499.4 | 343.1% |
| | | 3,660.2 | 5,779.1 | 9,633.2 | 12,597.8 | 16,689.5 | 356.0% |
| RFETS | Adams (CO) | 659.4 | 1,151.3 | 2,288.6 | 3,461.4 | 4,274.6 | 548.2% |
| | Arapahoe (CO) | 805.9 | 1,704.1 | 3,826.3 | 6,567.0 | 8,850.0 | 998.2% |
| | Boulder (CO) | 556.8 | 1,005.4 | 2,125.7 | 3,479.2 | 4,843.5 | 769.9% |
| | Denver (CO) | 2,469.1 | 3,830.5 | 6,029.7 | 8,610.0 | 10,334.9 | 318.6% |
| | Jefferson (CO) | 1,081.0 | 2,119.6 | 4,484.6 | 7,245.9 | 9,230.5 | 753.9% |
| | | 5,572.1 | 9,810.9 | 18,754.9 | 29,363.5 | 37,533.5 | 573.6% |
| SNL/NM | Bernalillo (NM) | 1,158.1 | 2,088.6 | 3,895.3 | 6,168.0 | 8,450.7 | 629.7% |
| | Cibola (NM) | 0.0 | 0.0 | 0.0 | 175.4 | 195.2 | NA |
| | Sandoval (NM) | 40.1 | 102.1 | 227.3 | 488.0 | 832.9 | 1974.7% |
| | Santa Fe (NM) | 192.8 | 352.3 | 677.2 | 1,140.1 | 1,704.0 | 784.0% |
| | Torrance (NM) | 13.4 | 25.7 | 52.6 | 76.1 | 107.9 | 703.1% |
| | Valencia (NM) | 97.1 | 179.2 | 436.2 | 369.9 | 532.2 | 448.0% |
| | | 1,501.5 | 2,747.9 | 5,288.6 | 8,417.4 | 11,822.9 | 687.4% |

## *Table C.4–19. Baseline Personal Income—Continued*

Total Personal Income ($ million)

| Site | County/State | 1970 | 1975 | 1980 | 1985 | 1990 | Percent Change 1970-1990 |
|---|---|---|---|---|---|---|---|
| SRS | Aiken (SC) | 306.6 | 484.2 | 860.5 | 1,359.6 | 2,172.4 | 608.6% |
| | Allendale (SC) | 21.5 | 35.1 | 59.3 | 88.5 | 127.5 | 493.5% |
| | Bamberg (SC) | 36.6 | 59.8 | 92.7 | 134.5 | 177.3 | 384.8% |
| | Barnwell (SC) | 46.3 | 84.1 | 129.4 | 209.5 | 285.8 | 517.2% |
| | Burke (GA) | 44.7 | 76.7 | 120.3 | 199.7 | 231.1 | 417.4% |
| | Columbia (GA) | 70.8 | 131.7 | 339.9 | 694.8 | 1,120.6 | 1483.3% |
| | Richmond (GA) | 500.3 | 820.7 | 1,369.8 | 2,233.2 | 3,023.5 | 504.3% |
| | Screven (GA) | 28.7 | 52.3 | 80.7 | 130.8 | 165.9 | 477.2% |
| | | 1,055.4 | 1,744.5 | 3,052.6 | 5,050.6 | 7,304.0 | 592.0% |
| SLAC | Alameda (CA) | 5,187.3 | 7,674.5 | 13,092.7 | 20,275.5 | 28,453.8 | 448.5% |
| | Monterey (CA) | 1,167.5 | 1,915.6 | 3,178.0 | 4,826.1 | 6,954.0 | 495.6% |
| | San Benito (CA) | 73.5 | 124.1 | 246.3 | 391.9 | 600.5 | 716.6% |
| | San Mateo (CA) | 3,277.2 | 4,970.5 | 8,595.9 | 13,341.5 | 18,789.9 | 473.4% |
| | Santa Clara (CA) | 5,220.4 | 8,610.2 | 16,910.5 | 27,071.3 | 37,882.5 | 625.7% |
| | Santa Cruz (CA) | 541.6 | 1,011.8 | 2,087.0 | 3,323.7 | 5,085.9 | 839.1% |
| | Stanislaus (CA) | 766.1 | 1,335.7 | 2,577.1 | 3,743.3 | 5,699.3 | 644.0% |
| | | 16,233.6 | 25,642.4 | 46,687.6 | 72,973.3 | 103,465.8 | 537.4% |
| UofMO | Audrain (MO) | 91.1 | 139.7 | 224.2 | 288.2 | 355.5 | 290.3% |
| | Boone (MO) | 269.9 | 474.9 | 890.4 | 1,320.1 | 1,935.4 | 617.1% |
| | Callaway (MO) | 84.6 | 131.5 | 268.3 | 368.3 | 487.9 | 476.6% |
| | Cole (MO) | 172.1 | 286.7 | 507.7 | 745.4 | 1,038.5 | 503.3% |
| | Cooper (MO) | 51.6 | 77.6 | 115.8 | 161.5 | 202.6 | 292.3% |
| | Howard (MO) | 33.8 | 47.1 | 72.3 | 103.1 | 129.9 | 284.8% |
| | Moniteau (MO) | 34.2 | 56.4 | 97.2 | 138.3 | 190.8 | 458.0% |
| | Randolph (MO) | 73.0 | 117.4 | 187.8 | 266.2 | 330.5 | 353.0% |
| | | 810.2 | 1,331.1 | 2,363.8 | 3,391.0 | 4,670.9 | 476.5% |
| WIPP | Chaves (NM) | 135.7 | 240.6 | 416.7 | 626.9 | 821.6 | 505.5% |
| | Eddy (NM) | 130.7 | 225.6 | 409.7 | 585.9 | 688.8 | 427.1% |
| | Lea (NM) | 167.1 | 289.6 | 558.2 | 778.5 | 744.5 | 345.6% |
| | Otero (NM) | 125.1 | 200.2 | 322.4 | 520.4 | 651.7 | 421.0% |
| | Culberson (TX) | 11.1 | 16.0 | 27.3 | 32.5 | 38.0 | 242.8% |
| | Loving (TX) | 0.4 | 1.1 | 2.1 | 2.1 | 2.7 | 507.2% |
| | | 570.1 | 973.1 | 1,736.3 | 2,546.3 | 2,947.3 | 417.0% |
| WSSR | Franklin (MO) | 189.3 | 316.9 | 614.9 | 956.8 | 1,323.3 | 598.9% |
| | Jefferson (MO) | 350.2 | 549.8 | 1,271.3 | 1,923.6 | 2,737.9 | 681.7% |
| | St. Charles (MO) | 372.9 | 606.0 | 1,454.9 | 2,610.8 | 4,036.8 | 982.5% |
| | St. Louis (MO) | 4,885.5 | 7,329.9 | 11,901.7 | 17,713.2 | 24,097.6 | 393.2% |
| | Madison (IL) | 995.1 | 1,470.2 | 2,459.0 | 3,350.6 | 4,487.0 | 350.9% |
| | Monroe (IL) | 66.2 | 109.7 | 212.4 | 307.2 | 465.9 | 603.5% |
| | St. Clair (IL) | 1,013.4 | 1,480.5 | 2,373.8 | 3,275.2 | 4,257.3 | 320.1% |
| | | 7,872.7 | 11,862.9 | 20,287.9 | 30,137.3 | 41,405.8 | 425.9% |
| WVDP | Cattaraugus (NY) | 269.9 | 405.5 | 633.5 | 850.3 | 1,152.5 | 327.1% |
| | Erie (NY) | 4,669.4 | 6,608.2 | 10,002.6 | 13,224.0 | 17,712.0 | 279.3% |
| | | 4,939.2 | 7,013.7 | 10,636.1 | 14,074.2 | 18,864.5 | 281.9% |
| UNITED STATES | | 825,534.0 | 1,308,482.0 | 2,254,076.0 | 3,317,545.0 | 4,664,057.0 | 465.0% |

Source: U.S. Department of Commerce, Bureau of Economic Analysis (1992a).

for the National economy, and then to estimate the proportion of relationships that are attributable to the regional economy under analysis. The technique involves matrix multiplication of the Bureau of Economic Analysis' 1987 *Use and Make Tables* (DOC, 1994) that results in a *National Direct Requirements Table*, as shown in the following example:

$$A_N = [USE_N] \times [MAKE_N]$$

where:

$A_N$ = National Direct Requirements Table,

$USE_N$ = 1987 U.S. Use Table, and

$MAKE_N$ = 1987 U.S. Make Table.

By using the Consumer Price Index (CPI) and the Producer Price Index (PPI), the 1987 data was updated to 1990 dollar terms. (The detailed PPI was used to update manufacturing and wholesale trade sectors, while the detailed CPI was used to update service and retail sectors.)

Once the interindustry relationships were identified in the *National Direct Requirements Table*, they were regionalized by calculating the location quotient for earnings (i.e., income to labor). The location quotient for output is given by:

$$LQ^R_i = [(X^R_i/X^R)/(X^N_i/X^N)]$$

where:

$LQ^R$ = Location quotient for region "R" and industry "i,"

$X^R_i$ and $X^R$ = output for industry "i" and total industry output in the region, and

$X^N_i$ and $X^N$ = National output for industry "i" and total output for the country (Miller and Blair, 1985).

Similarly, the income (earnings) location quotient matrix for industry "i" in region "R" is given by:

$$LQ^R_i = [(Y^R_i/Y^R)/(Y^N_i/Y^N)]$$

where:

$LQ^R$ = Location quotient for region "R" and industry "i,"

$Y^n$ and $Y^n$ = national income for industry "i" and total income for the Nation, and

$Y^R_i$ and $Y^R$ = income for industry "i" and total industry income in the region.

The *National Direct Requirements Table* (from above) was then multiplied by the vector of location quotients for a given region to derive a regional *Direct Requirements Table*. This process was repeated for each ROI.

The regional *Direct Requirements Table* is therefore:

$$A_R = [LQ_R] \times [A_N]$$

where:

$A_R$ = regional Direct Requirements Table for region "R," and

$LQ_R$ = Matrix of location quotients for region "R".

The following calculation resulted in the final matrix of impacts for a given region:

$$M_R = [I - A_R]^{-1}$$

where:

$M_R$ = matrix of output multipliers for region "R," and

I = the "identity" matrix (a matrix of zeros with ones on the diagonal).

The resulting 80-by-80-sector output multiplier table was then totaled across its rows (except for row 80) to produce a vector of output multipliers. Row 80 is the sum of earnings paid to households and is already incorporated in the multipliers for the first 79 sectors. Therefore, row 80 contains the earnings multipliers for a given region.

A final step was required to determine the employment multipliers for a region. Using County Business Pattern data for the Nation as a whole (DOC, 1993), the relationships between employment and output for all industries were derived.

The standard procedure in applying regional impact models is to calculate the specific multipliers (employment, income, and output as described above) for each of the 80 sectors individually, then multiply each industry multiplier by the costs anticipated for each industry sector. The difficulty with this approach is in transforming the data from an lump sum engineering cost estimate into the 80 industry classifications. The procedure used in this economic impact analysis was to assume that the individual multipliers are normally distributed. The mean multiplier for employment, income, and output was calculated for each

region and multiplied by the initial costs. The product is the change in employment, income, and output. Given a sample size of 80 sectors that are normally distributed, the sample size is large enough to approximate a standard normal distribution.

The advantage in using individual multipliers is their ability to trace impacts on the economic variables through individual industrial sectors. However, because the objective of this analysis was to look at marginal changes in total employment, income, and output—not at the changes in specific industrial sectors—such a detailed analysis was considered unwarranted.

The employment, income, and output multipliers for each region were then applied to the initial waste management project costs for each site under each waste-type alternative. As discussed above, the cost data were broken out into construction, operations, and transportation phases. When changes in employment and income were calculated for each waste-type alternative, they were weighted by the number of years involved for construction and operations activities. The percent change in employment and income is equal to the total time-weighted dollar change in the variable divided by the 1990 value of the variable, multiplied by 100.

The National-level impacts of waste management activities were calculated by using the National RIMS II multipliers. These impacts help to account for the leakage in expenditures that would occur at the regional level when purchases of goods and services must be made outside a particular ROI due to the inability of the regional economy to provide those goods or services. For example, steel is manufactured only in certain parts of the U.S. When steel is required by a site that is in an ROI that does not have a steel plant, the steel must be brought in from outside of the ROI. This purchase causes money "leakage" out of that ROI to somewhere else in the National economy. The National economy analysis is thus able to "capture" economic activity that is otherwise lost to the individual site ROIs.

Since the transportation expenditures would be made throughout the country, the National multipliers were also used to determine the impacts of transportation expenditures.

The next step was to multiply the respective grand mean multipliers for employment, income, and output respectively by the initial expenditure anticipated for each site and waste type alternative. The product of the initial cost and the multipliers gave the estimated change in personal income, job-years, and output.

### C.4.5.3.2 *Analysis Assumptions*

This section identifies the assumptions used in developing the baseline conditions and impacts for the various waste types.

### C.4.5.3.3 *Multiplier Analysis*

Baseline conditions for the impacts analysis used a two-tier ROI. The first tier included the 17 sites that contain the vast majority of DOE waste. A detailed ROI was developed based on the residence patterns of the site employees. Counties were included if they contained 5% or more of the site employees, until the counties selected accounted for 90% or more of the site employees. Contiguous counties were included by exception if there was reason to believe that excluding them might preclude a site-specific determination of where on a site a waste management facility could be located.

The second ROI tier included 37 sites that are anticipated to have relatively low expenditures, irrespective of the waste type or the Alternative. In most cases the second tier sites were waste donor sites. Since these sites will experience small impacts (due to little or no planned activity) they were not given the extensive treatment that the major sites received. The ROIs for each second tier site consists of the host and contiguous counties only.

As indicated above, multipliers were assembled for each of the ROIs associated with each site. The simplifying assumption regarding these multipliers holds that the average (mean) multiplier is an unbiased and efficient estimator of the any of the 80 multipliers.

Each waste type was analyzed using specific timing assumptions. Further, the HLW analysis used different timing assumptions for each alternative. The time frames identified in Table C.4–20 and employed in the analysis should be viewed as representative. Representative time cycles are used to show what would happen if a similar cycle were actually used. The time frame is required to annualize the changes in income and employment both to provide the absolute change in the variable and the percent change over the 1990 baseline. The time frames are proxies for any time period and are not intended to imply that a particular time frame has been selected.

*Table C.4–20. Duration in Years of WM Activity Phases Assumed for Waste Type Economic Analysis*

| Waste Type | Construction Phase[a] | Operations Phase | Transportation |
|---|---|---|---|
| LLMW | 4 | 15 (No Action = 25) | 10 (No Action = 20) |
| LLW | 4 | 15 (No Action = 25) | 10 (No Action = 20) |
| TRUW | 4 | 15 (No Action = 25) | 10 (No Action = 20) |
| HLW | 3 | 17 to 43[b] | 34 |
| HW | 4 | 12 | 10 |

[a] Assumes 4 years of actual construction activity within a 10-year time frame to plan and implement facility construction.
[b] Varies with site and alternative.

In addition, it was assumed that an additional five years will elapse before the full economic impacts of any given or phase of the operation will occur. The time frame used to calculate impacts then includes the time over which the action is planned to occur plus five years.

The economic impact analysis was based on standard Keynesian economic theory. This theory holds that aggregate demand is a function of income. When income is generated in the form of a wage, several deductions are made reducing the amount of money that is available for respending. These deductions are given in Table C.4–21.

A coefficient of variance was calculated for the grand mean multipliers of the ROIs for the 47 sites. The coefficient of variance is equal to the standard deviation of the grand mean multiplier divided by the grand mean multiplier.

The grand mean multipliers and the multipliers' coefficient of variance for the 47 ROIs are reported in Table C.4–22 and Table C.4–23, respectively.

***Table C.4–21. Wage Deductions Used in the Income Multiplier Analysis***

| Deduction | Percentage of Deduction |
|---|---|
| Federal income tax | 18.0 |
| Social security tax | 7.6 |
| State unemployment tax | 1.5 |
| Benefits (health and life insurance) | 2.0 |
| Personal savings | 5.0 |
| Total unavailable for respending | 34.1 |
| Total available for respending | 65.9 |

### C.4.5.3.4 *Limitations of the Multiplier Analysis*

The use of the input-output (I-O) system for estimating multipliers has several limitations, including:

- No explicit recognition of prices. Relative prices between industries change, and the prices are not updated. The most complete table in use today uses 1987 prices; price adjustments are made uniformly and do not capture changes in relative prices within an industry.
- Linear homogeneous production function. If any scale economies or diseconomies exist, they are not captured; expansion of one industry will not have the impacts on downstream industries that the I-O model assumes.
- Constant I-O formation ignores the possibility that capacity will be reached with the effect of changing relative prices and input substitutions.

While these limitations are important, the use of the multipliers is to show relative changes, i.e., what would happen if you did a similar thing in different places. While the limitations prevent the determination of the absolute changes in the magnitude of the economic variables, they are instrumental in identifying relative changes.

### *Table C.4–22. Grand Mean Multipliers*

| Site | Output (1) | Earnings (2) | Employment (3) |
|---|---|---|---|
| Ames | 1.8968398 | 0.2686351 | 26.1 |
| ANL-E | 1.8992364 | 0.2794387 | 24.1 |
| BCL | 2.0945444 | 0.2963150 | 27.2 |
| Bettis | 2.0854729 | 0.2955736 | 26.8 |
| BNL | 1.8928028 | 0.2825461 | 24.9 |
| Charleston | 1.8486995 | 0.2632758 | 24.2 |
| Colonie | 1.9521110 | 0.2755395 | 26.0 |
| ETEC | 2.0860979 | 0.2918617 | 26.9 |
| Fermi | 2.1277356 | 0.3000036 | 27.1 |
| FEMP | 2.0115936 | 0.2992522 | 26.2 |
| GA | 1.9761869 | 0.2793827 | 26.2 |
| GE | 1.8819248 | 0.2698297 | 26.0 |
| GJPO | 1.8788433 | 0.2628304 | 25.5 |
| Hanford | 1.7345193 | 0.2606101 | 24.4 |
| INEL | 1.6539740 | 0.2501210 | 23.2 |
| KCP | 2.0661073 | 0.2920600 | 26.9 |
| KAPL-K | 1.6542548 | 0.2492809 | 22.1 |
| KAPL-N | 1.8803463 | 0.2665589 | 25.2 |
| KAPL-W | 2.0211218 | 0.2872877 | 26.0 |
| LEHR | 1.8814520 | 0.2667942 | 25.2 |
| LBL | 2.1162016 | 0.3093407 | 26.8 |
| LLNL | 2.1480631 | 0.3114184 | 28.2 |
| LANL | 1.7278235 | 0.2566492 | 23.6 |
| Mare Is | 2.0097511 | 0.2841494 | 26.5 |
| Middlesex | 2.0560625 | 0.2908983 | 26.2 |
| Mound | 1.7815385 | 0.2537604 | 23.7 |
| NTS | 1.7526830 | 0.2633199 | 23.4 |
| Norfolk | 1.7882339 | 0.2551058 | 23.9 |
| ORR | 2.0175825 | 0.3014903 | 26.7 |
| PGDP | 1.7091768 | 0.2612092 | 23.9 |
| Palos | 2.1394955 | 0.3019226 | 27.2 |
| Pantex | 1.8058253 | 0.2664281 | 24.8 |
| Pearl H | 1.8166110 | 0.2560974 | 24.3 |
| Pinellas | 1.9382666 | 0.2750944 | 25.8 |
| PORTS | 1.7395320 | 0.2644895 | 24.8 |
| Ports Nav | 2.0104574 | 0.2857046 | 26.3 |
| PPPL | 2.0962324 | 0.2967151 | 26.8 |
| Puget So | 1.9194054 | 0.2736098 | 25.3 |
| RMI | 1.8073449 | 0.2559203 | 23.4 |
| RFETS | 1.9088693 | 0.2832914 | 25.2 |
| SNL/NM | 1.8358633 | 0.2730185 | 24.9 |
| SRS | 1.8961558 | 0.2789010 | 25.8 |
| SLAC | 1.7502934 | 0.2507150 | 23.3 |
| UMo | 1.7537006 | 0.2497958 | 24.0 |
| WIPP | 1.7094931 | 0.2559931 | 23.7 |
| WSSR | 2.1302335 | 0.3014761 | 27.3 |
| WVDP | 2.1326031 | 0.3170268 | 27.8 |
| National | 3.0829564 | 0.8324667 | 36.8 |

***Table C.4–23. Multipliers' Coefficient of Variance[a]***

| Site | Output | Earnings | Employment |
|---|---|---|---|
| Ames | 0.1282514 | 0.3232824 | 0.7017540 |
| ANL-E | 0.1514593 | 0.4842782 | 0.6223096 |
| BCL | 0.1335457 | 0.3108199 | 0.5816449 |
| Bettis | 0.1423880 | 0.3197699 | 0.5657588 |
| BNL | 0.1076392 | 0.4656121 | 0.6015071 |
| Charleston | 0.1350718 | 0.3236767 | 0.6538367 |
| Colonie | 0.1183233 | 0.3023482 | 0.6448926 |
| ETEC | 0.1194562 | 0.3069452 | 0.5785328 |
| Fermi | 0.1395721 | 0.3117937 | 0.5540122 |
| FEMP | 0.1212080 | 0.4434402 | 0.5735707 |
| GA | 0.1184384 | 0.3187351 | 0.6262334 |
| GE | 0.1310743 | 0.3253468 | 0.7018351 |
| GJPO | 0.1458825 | 0.3387602 | 0.7130032 |
| Hanford | 0.1291553 | 0.4987933 | 0.7501411 |
| INEL | 0.1174174 | 0.5183568 | 0.7851976 |
| KCP | 0.1249323 | 0.3062415 | 0.5880993 |
| KAPL-K | 0.1055506 | 0.5082354 | 0.6985579 |
| KAPL-N | 0.1108195 | 0.3142466 | 0.6520623 |
| KAPL-W | 0.1330296 | 0.3176867 | 0.5789079 |
| LEHR | 0.1195645 | 0.3213139 | 0.6552262 |
| LBL | 0.1336941 | 0.4379207 | 0.5548303 |
| LLNL | 0.1299192 | 0.4302718 | 0.6280589 |
| LANL | 0.1234926 | 0.5115640 | 0.7293250 |
| Mare Is | 0.1336816 | 0.3163528 | 0.6208246 |
| Middlesex | 0.1337611 | 0.3137265 | 0.5703249 |
| Mound | 0.1183593 | 0.3377189 | 0.7091450 |
| NTS | 0.1305871 | 0.5074167 | 0.6517835 |
| Norfolk | 0.1225205 | 0.3380128 | 0.6498472 |
| ORR | 0.1279087 | 0.4467180 | 0.5916954 |
| PGDP | 0.1297143 | 0.5055180 | 0.7517458 |
| Palos | 0.1399090 | 0.3116253 | 0.5491915 |
| Pantex | 0.1236165 | 0.4922549 | 0.7415270 |
| Pearl H | 0.1267270 | 0.3324984 | 0.6697828 |
| Pinellas | 0.1146860 | 0.3179148 | 0.6247028 |
| PORTS | 0.1408416 | 0.5007350 | 0.7359551 |
| Ports Nav | 0.1414415 | 0.3262595 | 0.5881818 |
| PPPL | 0.1343447 | 0.3116302 | 0.5635358 |
| Puget So | 0.1342005 | 0.3296160 | 0.6086124 |
| RMI | 0.1327751 | 0.3383731 | 0.6790840 |
| RFETS | 0.1261521 | 0.4754906 | 0.6146155 |
| SNL/NM | 0.1197497 | 0.4900238 | 0.6760818 |
| SRS | 0.1370186 | 0.4650688 | 0.7017991 |
| SLAC | 0.1079955 | 0.3308188 | 0.6862206 |
| U of Mo | 0.1305158 | 0.3448562 | 0.7495700 |
| WIPP | 0.1205319 | 0.5070867 | 0.7579089 |
| WSSR | 0.1401402 | 0.3130342 | 0.5595690 |
| WVDP | 0.1362926 | 0.4282287 | 0.5648346 |
| National | 0.1816865 | 0.2830192 | 0.3542612 |

[a] The coefficient of variance is equal to the standard deviation of the mean multiplier divided by the mean.

### C.4.5.3.5 *Analysis Data*

Most of the baseline data used in this analysis are from the Bureau of Economic Analysis whose "Regional Economic Information System" provides historical data on employment and personal income.

The cost figures used in the analysis include the fully loaded costs of setting up a business to build and operate the WM facilities. They also include a set of linear scaler modules that can be assembled on the basis of the type of waste and waste volume. The modules can be placed in any part of the country and either scaled to accommodate the volume of waste, or adjusted in terms of the number of operating years to accommodate different waste volumes. The cost figures include a 30% contingency.

### C.4.5.3.6 *Evaluation Techniques*

The economic model outputs included changes in income, output, and job-years. When the timing assumptions were applied, the job-years variable was divided by the number of years to give the number of direct, indirect, and induced jobs in an ROI. All of the ROIs that were evaluated are anticipated to experience an increase in expenditures resulting in increases in employment, income, and output; therefore, all impacts are expected to be positive.

The primary evaluation technique is to identify the magnitude of the change. All of the impact categories are first measured in absolute terms. Then, income and employment inputs are calculated with respect to changes in the baseline income and employment.

### C.4.5.3.7 *Presentation of Results*

Data from the analysis are presented in several places in the WM PEIS document. Chapter 4 provides affected environment data for the 17 major sites in text and tables. The additional sites are presented in the *Technical Report on Affected Environment for the DOE Sites Considered in the DOE Waste Management Programmatic Environmental Impact Statement* (DOE, 1995b). Chapters 6 through 10 present the results of the impacts analysis for each of the waste types and for each alternative. The primary variable in these chapters is the percent change in the number of jobs. Changes in personal income are also presented. Both

variables are presented in terms of absolute numbers as well as percent changes over the 1990 baseline. A 1% change in the number of jobs is considered a substantial positive benefit to the regional or National economy.

### C.4.6 POPULATION IMPACTS

The analysis examined the potential for the waste management alternatives to cause the types of impacts that could result when any large industrial or public works project attracts workers and their families to an area.

#### C.4.6.1 Regions of Influence

The ROI included the geographic area surrounding the site that would be subject to the changes traditionally associated with large-scale industrial projects (such as changes in employment and demographics). The site-level ROI was defined, as an aggregate of whole counties to include the host county (or counties), any contiguous counties, and other counties within the region that contain at least 5% of the total site workforce (both DOE and contractor personnel). Where these counties did not represent at least 90% of the total site workforce, counties with progressively lower percentages were included until the 90% threshold was met.

The site ROI population was assumed to represent the affected community at each site. It was considered reasonable to expect that the effects of in-migration to a region would be experienced in existing, nearby communities that have the infrastructure and established community support networks necessary for social life.

The analysis quantified population changes that constitute or that may in turn cause a number of related changes in community characteristics and that are likely to affect community services and resources. The likelihood of these latter effects is inferred from the size of the expected temporary and permanent population changes during the construction and operations phases of the waste management projects and the general characteristics of the communities at each site.

### C.4.6.1.1 *Potential Impacts of WM Project Labor Requirements*

Population increases and settlement patterns associated with worker in-migration to the ROI are the source of most social effects of the construction and operation of an industrial project. (Halstead et al., 1984; Canter, 1977). Sources of change include the introduction of new people into a region in response to new employment; loss of residents in response to a perceived diminished quality of life or loss of employment opportunities; or retention of residents, who might otherwise have left the area, as a result of improvement or enhancement of some social factor.

The construction and operation of waste management facilities can be expected to have some influence on the growth of the population in the regions surrounding the sites. This growth will raise important concerns based on the potential for changes to certain community characteristics such as size, diversity, stability, and the ability to provide necessary or locally desirable social services. Though the description of the precise nature and detail of these changes is dependent on site specific information regarding the location of any proposed facility, the size and characteristics of the inmigrating workforces and the number of existing site personnel actually employed on the project, some preliminary estimates can be made on the basis of the more general information available at the programmatic level.

#### C.4.6.1.1.1 Community Characteristics—Size, Diversity, Stability

Conventional effects associated with large industrial facilities include: the economic effects of increased local employment, the demographic effects of increased population growth, the fiscal effects of increased demands for social services, and social effects of perceived changes in the quality of life (Finley, 1983). These changes will usually result in other changes in community life. The temporary in-migration of construction workers and their families and the more permanent settlement of workers during the operations phase of the proposed action are relevant to this analysis.

The central impetus for change rests in the differences, both real and perceived, between the incoming population and those who already reside in the ROI. Important demographic characteristics that could change include age, sex, ethnic and racial composition, and income distribution. Potential disruptions to settlement patterns and relocation of local population are also important (Canter, 1993). Consequential

changes in the patterns of interaction of local residents also can be anticipated (Gramling and Freudenburg, 1992).

Other associated changes include: the level of diversity and complexity—affected when the number and types of social groups in the community are increased; and community cohesion—potentially affected by anything that decreases the desirability of the community itself or the desirability of associating or identifying with the community (Finsterbusch, 1980).

#### C.4.6.1.1.2 Community Services and Resources

Local community resources and especially the provision of services (health, education, and public safety services) to community residents are susceptible to any change in the size and composition of the local population (Canter, 1993). Along with community social and welfare services, these social services constitute primary resources to the populations of the affected communities. The mechanisms for providing these services can be disrupted by population growth or change in composition or location of the population. Other social resources, such as available housing and recreational and cultural resources, may also be affected by temporary or long-term in-migration. Project related growth is expected to increase demands for services provided by local and State governments in the affected regions.

Although it is not feasible to collect data on the capabilities of individual community service delivery systems without specific information regarding the physical location of the designated facility and the corresponding distribution of new population in the ROI, some qualitative prediction of impacts can be made on the basis of general population estimates. Impacts to social services and resources can be inferred from the direct and indirect labor requirements and associated changes in population size and mix anticipated for each of the alternatives. Impacts may be predicted on the basis of the potential for altering service provider to recipient ratios, such as student/teacher or doctor/patient ratios; decreased availability of facilities such as hospital beds or schoolroom seats; or the loss of services to segments of the community as a result of overcrowding or population relocation. A sudden need to provide resources to expand services or an increased capability to provide resources based on an increased population would cause fiscal impacts.

### C.4.6.1.2 *Method of Population Analysis*

Because the factors that influence in-migration are multiple and complex, it was impossible to precisely predict the number of in-migrants at each site for the proposed alternatives. However, an estimate was made for each site based on total waste management project workforce requirements. Although this number is not a specific prediction of the actual in-migration into a site's ROI, it provides a basis for comparing potential changes in population across alternatives.

This analysis considered three types of in-migration associated with new requirements for (1) direct construction labor; (2) O&M labor; and (3) secondary labor resulting from new employment at the sites. The level of in-migration would be indirectly influenced by several factors: the current level of unemployment in the region; the economic conditions and the demands for labor (both within the region and in adjacent areas); the ability of the local workforce to provide the necessary skills; the presence and success of worker retraining programs; characteristics of workers and their families; and individual preferences for location and type of residence. The location and the personnel requirements of contractors who work on the project would also be factors; some may already be located in the region with available staff to meet the work requirement, while others may be located outside the region.

Other factors that would influence in-migration include the size of the project and proximity of the region to urban centers. Indirect employment and induced employment (additional employment in the region that is not directly connected to the project but results from increased expenditures in the region) would also contribute to changes in the resident population and to the general social character of the region.

This approach assumed that the following factors remain constant for all alternatives: worker family characteristics, residential locations, composition of the local workforce, and labor shortages among specific occupational groups in the region. No attempt was made to estimate the potential for in-migration that exceeds the number of jobs provided; only estimates of actual employment, direct and multiplier-based, are used. Estimates of peak employment or singular shortages of particular labor categories at particular sites are not included. The success rates of retraining programs at individual sites may affect the availability of labor, but this factor cannot be correctly appraised for this assessment.

The potential for the cumulative effect of this action and the other planned or foreseeable projects at the site to cause a rapid increase in population migration to the region of influence is a serious consideration for

the analysis of site-level impacts. The assessment of population impacts is therefore based on a conservative approach intended to highlight those actions and alternatives that could cause a rapid-change effect. This is especially important during the construction phase when peak periods for many projects may cause a sudden sharp increase in temporary employment at the site. Because the actual timing of future peak employment periods is not known, only a very general discussion is possible at the programmatic level. However, peak-period employment is provided in *Waste Management Environmental and Socioeconomic Impacts Methods and Results* (DOE, 1996a) as a guide to later site-specific analyses.

The actual number of in-migrants during any phase of the waste management project could not be precisely determined, but the literature provides some base assumptions and empirical data that were used in developing percentage estimators for the WM project phases based on the phases of similar projects:

- The percentage of construction jobs filled by in-migrants would be expected to range from 30 to 60% (Halstead et al., 1984). The actual figures for specific projects vary according to the following factors:
  - Size of the project
  - Proximity to urban centers
  - Local labor force
  - Requirement for specialized skills and crafts
  - Table C.4–24 lists the percentages for each of the 17 major sites based on the characteristics of the site ROI
- Job duration during the construction phase was assumed to be approximately four years, and most (85%) of in-migrant construction workers who are directly related to the project are phased out after this period.
- Local workers occupy 40 to 60% of new O&M jobs. Training or retraining programs may encourage local hiring. Because DOE has plans for a retraining program, it is assumed that no fewer than 40% of the available jobs will go to retrainees, 30% will go to other local workers, and 30% will go to in-migrants.
- Of all induced labor associated with the project, 50% will be hired from the local workforce.

For the quantitative estimate of population in-migration and associated characteristics, impacts are presented in the waste-type chapters for those sites where ROI population increases (including new workers and their families) were estimated to be 1% or greater than the 1990 population. This criterion assumes a minimum 1% surplus capacity in public service delivery systems, infrastructure, and other health and welfare services. An increase of less than 1% would also not normally be expected to change the general

*Table C.4–24. Percentage of Construction Workers Expected to In-Migrate to Each of the 17 Major DOE Sites*

| Percentage | Sites |
|---|---|
| 30 | BNL |
| 40 | ANL-E, FEMP, LLNL, ORR, RFETS, SNL/NM, WVDP |
| 45 | Hanford, NTS |
| 60 | INEL, LANL, PGDP, Pantex, PORTS, SRS, WIPP |

distribution of demographic characteristics within the population as a whole (e.g., change the character of the population by changing the percentage of the population in a given category such as gender, marital status, etc.). These sites are assumed by the analysis to experience a greater potential for change to the social environment as a result of the proposed action. Additionally, sites with estimated population increases over one-half of 1% were assumed to have a potential for minor impacts to social characteristics and the provision of social services and are noted in the discussion where appropriate.

Because the precise location of new facilities at a site and the subsequent preferred residential location of in-migrating workers are not known, this assessment serves only as an estimate for the purpose of comparing impacts. Noticeable effects may occur at much lower levels than 1%, if in-migration is concentrated in one or two communities.

## C.4.7 Environmental Justice Impacts

In accordance with the requirements of Executive Order 12898, DOE evaluated the potential for the WM PEIS program alternatives to cause disproportionately high and adverse human health or environmental effects on minority and low-income populations. DOE identified minority and low-income populations residing within 50 miles of the 17 major sites, then reviewed the human health effects and environmental impacts associated with alternatives for the five waste types at those sites. The review included potential impacts under each of the major scientific disciplines evaluated for the waste-type alternatives—human health risk, air quality, water resources, ecology, economics, population impacts, land use, infrastructure, and cultural resources impacts. Regarding health effects, normal facility operations were examined, with accident scenarios evaluated in terms of the risk to the public.

Environmental justice analysis for specific transportation routes was not done because specific routes were not analyzed in the transportation risk analyses. While a disproportionate share of minorities in the population resides near interstate highways and railroads, the major risks to the public from truck transportation are to travelers on the highways from the physical impact of accidents and routine exposure during rest stops. In both cases, on the interstate highways where these major risks would be incurred, the same minorities are found to be disproportionately lower in representation (DOT, 1992). Therefore, minorities are not expected to be receiving a disproportionately higher share of the truck transportation risks.

For rail shipments, the primary risks to the public are from radiological exposure during classification in railyards, primarily at the start and end of each shipment, and from emissions of diesel exhaust from trains in urban areas. Although adverse impacts could occur in the unlikely event of a high-consequence accident, any potential disproportionality with respect to any population—minority, low income and/or American Indian populations included—is subject to the randomness of the combination of factors that can produce such impacts.

### C.4.7.1 Environmental Justice Overview

Environmental justice means the fair treatment of people of all races, cultures, and income levels with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (EPA, 1994a). Environmental justice impacts refer to adverse effects that result when one or more of a broad range of factors tends to place disproportionate adverse environmental impacts on minority (specifically including Native American) and low-income populations.

> ***A Word About Equity and Economics***
>
> *The environmental justice analyses presented in this document look only at risk and population characteristics near sites. The analyses do not attempt to weigh positive economic effects associated with increased treatment, storage, and/or disposal against associated risk.*

#### C.4.7.1.1 *Issuance of the Executive Order on Environmental Justice*

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority and Low-Income Populations*, became effective when signed on February 11, 1994. The Executive Order requires all 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 and low-income populations. The Executive Order also requires federal agencies to provide minority and low-income communities access to information and public participation in matters relating to environmental justice. Additionally, to the extent practicable and appropriate, agencies must examine consumption patterns of fish and wildlife where they may be affected by agency activities. Risks inherent in such consumption must be communicated to at-risk populations.

EPA has convened an interagency Federal Working Group on Environmental Justice to provide guidance to Federal agencies on criteria for identifying disproportionately high and adverse human health or environmental effects on minority and low-income populations, and to serve as an information clearinghouse, coordinate research and data collection, disseminate existing data and studies, provide public participation, organize interagency model projects, and deal with other environmental justice issues that require cooperation among Federal agencies. DOE is a member of the Working Group.

Under the Executive Order, agencies are required to develop agency-wide environmental justice strategies to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of the agency's programs, policies, and activities on minority and low-income populations. Using the strategy, the agency is required to conduct its programs, policies, and activities that "substantially affect human health or the environment" in a manner that insures that they do not subject persons (including populations) to discrimination.

Federal agencies are required to implement the Executive Order consistent with and "to the extent permitted by existing law." However, the Executive Order is intended only to improve the internal management of the Executive branch and does not create "any right, benefit, or trust responsibility, substantive or procedural, enforceable at law or equity by a party against the United States, its agencies, its officers, or any person." The Executive Order is not to be construed to create any right to judicial review involving the compliance or noncompliance of the United States, its agencies, its officers, or any other person. A memorandum for the heads of all departments and agencies, circulated with the Executive Order,

underscored the application of Title VI of the Civil Rights Act of 1964, NEPA, the Freedom of Information Act, the Sunshine Act, and the Emergency Planning and Community Right-to-Know Act as existing law particularly applicable to environmental justice (Office of the President, 1994).

"Minority and low-income populations" are not defined under the Executive Order. Consequently, U.S. Bureau of Census definitions, which appear in a variety of documents examining environmental justice impacts, were used. Generally, as defined by the U.S. Department of Commerce, Bureau of Census, minority populations include Black, American Indian, Asian-Pacific, and Hispanic racial and ethnic categories. Native American populations are specifically identified under the Order. Low-income populations are those whose income level is below the poverty level, also as defined by the Bureau of Census (DOC, 1992c,d). A more comprehensive definition of these two groups is presented in Section C.4.7.2.1.1.

#### C.4.7.1.2 *Status of Guidance on Environmental Justice*

Although the Working Group has not issued final guidance on the approach to be used in analyzing environmental justice, it has issued draft definitions of terms in the *Draft Guidance for Federal Agencies on Key Terms in Executive Order 12898*, dated November 28, 1994. These definitions, with slight modifications, were used in the PEIS environmental justice analysis. Further, in coordination with the Working Group, the Council on Environmental Quality issued Draft Guidance on May 24, 1996. DOE is also in the process of preparing internal guidance for the implementation of the Executive Order. Because both DOE and the Working Group are still in the process of developing final guidance, the approach used in this analysis might depart somewhat from whatever guidance is eventually issued.

### C.4.7.2 Approach to WM PEIS Consideration of Environmental Justice Impacts

Any assessment of environmental justice concerns rests on an examination of the composition of the population potentially affected by a given project or action. The potential of a given project or action to unfairly or "disproportionally" affect one segment of the population can be measured, in part, by determining the proportion of the potentially affected population that is minority or low-income. Once minority and low-income proportions of an affected population are identified, any potential impact or

human health effect from a given project or action that is determined to be potentially adverse can be examined in the context of its likelihood to disproportionately affect one or both of these population groups.

For the environmental justice assessment, the following effects, based on definitions by the Working Group, were evaluated for alternatives under each of the five waste types:

- Disproportionately high and adverse human health effects—Any human health effect from exposure to environmental hazards that exceeds generally accepted levels of risk and affects minority and low-income populations at a rate that appreciably exceeds the rate for the general population. Adverse health effects are measured in risks and rates that could result in latent cancer fatalities, as well as other fatal or nonfatal adverse impacts to human health.
- Disproportionately high and adverse environmental impacts—A deleterious environmental impact determined to be unacceptable or above generally accepted norms. A disproportionately high impact refers to an environmental hazard with a risk or rate of exposure for a low-income or minority population that appreciably exceeds the risk or rate of exposure for the general population.

### C.4.7.2.1 *Identification and Mapping of Minority and Low-Income Populations*

In order to determine the degree or existence of disproportionality, demographic information obtained from the U.S. Bureau of the Census was integrated into a geographic information system to identify minority and low-income populations residing in a zone of potential impact surrounding each of the sites under consideration. This zone was defined as a circle with a 50-mile radius, and whose center was either at the site center for the smaller DOE sites or at an existing waste management location for the six larger DOE sites (Hanford, INEL, LANL, NTS, ORR, and SRS). This 50-mile radius was selected because it was judged to encompass virtually all of the human health risks and environmental impacts that may occur. It was used to capture the offsite population at risk in the human health risk assessment of airborne dispersion of waste management facility emissions. It also encompasses the majority of communities that would be affected socioeconomically by waste management program actions.

#### C.4.7.2.1.1 Definitions

The following definitions were used to analyze the composition of populations residing around each site and to generate the maps presented in this appendix (see Figures C.4–7 through C.4–40, presented after Section C.4.7.2.3).

- A ***census tract*** is an area defined for the purpose of monitoring census data that is usually comprised of between 2,500 and 8,000 persons. When first delineated, census tracts are designed to be homogenous with respect to population characteristics, economic status, and living conditions. Census tracts do not cross county boundaries. The spatial size of census tracts varies widely depending on the density of settlement. Census tract boundaries are delineated with the intention of being maintained over a long period of time so that statistical comparisons can be made from census to census. For census tracts that were only partially inside the 50-mile radius, an even population distribution was assumed for the tract area and population was calculated as a proportion of the tract area inside the 50-mile radius (i.e., if 40% of the tract area was inside the 50-mile radius, 40% of the tract population was counted).
- A ***minority population*** is a group of people and/or community experiencing common conditions of exposure or impact that consists of persons classified by the U.S. Bureau of the Census as Negro/Black/African-American, Hispanic, Asian and Pacific Islander, American Indian, Eskimo, Aleut, or other nonwhite, based on self-classification by the people according to the race with which they most closely identify. In order to avoid double-counting minority Hispanic persons (Hispanics can be of any race), only white Hispanics were included in the tabulation of racially based minorities. Nonwhite Hispanics had already been counted under their respective minority racial classifications (e.g., Black, American Indian). For purposes of this analysis, a minority population consists of any census tract within the 50-mile zone of impact with a minority population proportion greater than the national average of 24.4%.
- A ***low-income population*** consists of persons of low-income status. Low-income status is based on U.S. Census Bureau data definitions of individuals living below the poverty line. The poverty line is defined by a statistical threshold that considers family size and income. For 1990, the poverty line threshold for a family unit consisting of four individuals, based on 1989 income, was $12,674. For purposes of this analysis, a low-income population consists of any census tract within the 50-mile zone of impact at each site that has a low-income population proportion greater than the national average of 13.1%.

#### C.4.7.2.1.2 Mapping Procedures

For each of the 17 major WM sites, demographic maps were generated through a geographic information system that utilized 1990 census data available from the U.S. Bureau of the Census. Maps of the minority and low-income populations residing within 50 miles of the DOE sites are shown in Figures C.4–7 through C.4–40, which follow Section C.4.7.2.3. Federally recognized Native American tribal lands within 50 miles of each site were also identified and mapped and are included in this appendix (see Figures C.4–7 through C.4–23). These maps are based on 1990 U.S. Bureau of the Census Tiger Line files, which contain political boundaries and geographical features, and Summary Tape Files 1 and 3, which contain demographic information (DOC, 1992c,d). Data were resolved to the census tract group level.

### C.4.7.2.2 *Review of High and Adverse Health Risks and Environmental Impacts*

The environmental justice analysis presented in each waste-type chapter is based on a review of the findings of the risk assessment for public health effects from proposed WM activities at each site and from transportation of wastes. If the PEIS human health risk assessment findings indicated that risks to the general population residing within 50 miles of each site would be low, then it was reasonable to conclude that no segment of the population would experience disproportionately high and adverse health risks, including any minority or low-income populations.

DOE has not evaluated the human health risk to subpopulations that may derive a portion of their food supply from native plants and animals that live near the DOE sites. The results of such a complex analysis would likely vary widely both within and among sites, depending on the assumptions used for such parameters as locations of waste management facilities on the sites, routes of exposure, and dietary habits. Thus, the results would not help to clarify the programmatic decision. The risk to human health for ingesting native plants and animals cannot be fully analyzed with confidence until the locations of facilities on the sites are known, the routes of exposure explicitly defined, and the dietary habits of affected subpopulations quantified. Therefore, analysis of health effects from subsistence consumption of fish, wildlife, and native plant species is not included in the WM PEIS but may be considered in sitewide or project-specific NEPA documents.

The analysis also reviewed environmental impacts, focusing on such effects as air quality, where adverse environmental effects could lead to adverse health effects. Once again, disproportionately high and adverse

impacts on minority or low-income groups would not be expected where the risks to the general population from environmental impacts would be low. Where risks or environmental impacts were found to be adverse, mitigation measures are described that could minimize impacts and thus eliminate the potential for disproportionately high impacts to any minority or low-income populations that might be affected.

#### C.4.7.2.3 *Analysis of Risk and Environmental Justice Impacts*

The following screening criteria, based on the WM PEIS risk analysis, were used to determine which WM sites would be analyzed for potential environmental justice concerns (generally over a 20-year operating period):

- A population risk greater than or equal to one latent cancer fatality from incident-free treatment facility operations
- A nonworker MEI cancer fatality probability of $1 \times 10^{-6}$ or greater from incident-free treatment facility operations (*Risk Assessment Guidance for Superfund* [EPA, 1989])

If a WM site had projected health risks greater than or equal to the conditions described in either of the two screening criteria, regardless of waste type or WM program alternative, further analysis was justified. Conversely, an analysis of potential environmental justice impacts at a particular site was not warranted if health risks were projected to be lower than those described in both criteria. If a particular alternative did not generate health effects exceeding these screening criteria, no disproportionately high and adverse health effects would be expected. Consequently, no environmental justice impacts would be expected, even if the population surrounding a site had minority or low-income proportions greater than the national average.

For the analysis of potential environmental justice impacts from treatment facilities operations, screening (at least one latent cancer fatality) was used to identify sites and alternatives needing further analysis. For sites with projected health effects associated with a specific waste type exceeding the screening limits, a sector block analysis was conducted. A grid consisting of 16 pie-shaped sectors (see Figure C.4–7) positioned 360° around the centroid of a site and 10 concentric circles (with interval sizes of 1, 5, and 10 miles) radiating outward from the centroid to the outer edge of the ROI was used to break down the ROI into sectors and blocks. A block consisted of the portion of a sector bounded by (or located between) concentric circles. The WM PEIS risk analysis was used to derive a sector block dose value (or unit concentration), which was distributed to each tract within a sector block. For tracts that crossed sector block

boundaries, the dose value was weighted according to the fraction of the tract occupying the sector block. After a dose value was assigned to each tract, the tract was classified as either minority or not (or low-income or not). An examination of the tracts receiving the highest doses was conducted to determine the proportion of these tracts that were minority or low-income. If the proportion of minority or low-income tracts receiving higher doses was higher than the proportion of minority or low-income tracts in the general population, an environmental justice impact was declared. Two additional analytical steps were performed. The same analysis was performed using only the census tracts receiving the upper 10% of the dose. In addition, the statistical correlations for dose and percentage minority and low income were calculated for LANL, the only site meeting the selection criterion for population risk.

To determine whether impacts to a nonworker MEI at WM sites under the various waste type alternatives could be disproportionate, a screening criterion (a nonworker MEI cancer fatality probability of $1 \times 10^{-6}$ or greater from incident-free operations) was used to identify sites requiring further analysis. Once these sites were identified, WM PEIS risk modeling was reviewed to locate the sector block containing the nonworker MEI for each selected site. A demographic analysis of the MEI sector block was then conducted to determine the composition of the census tract population. If the MEI sector block was composed of minority or low-income census tracts, a finding of potential for disproportionate health effects was included in the discussion of impacts for the relevant waste type and alternative. In most cases where more than one census tract was located in the MEI sector block, the tract located closest to the site was used to determine potential disproportionality. This approach was conservative and did not take credit for the possibility that, proportionately, the aggregate population of the MEI sector block may not exceed the national average for minority or low-income populations.

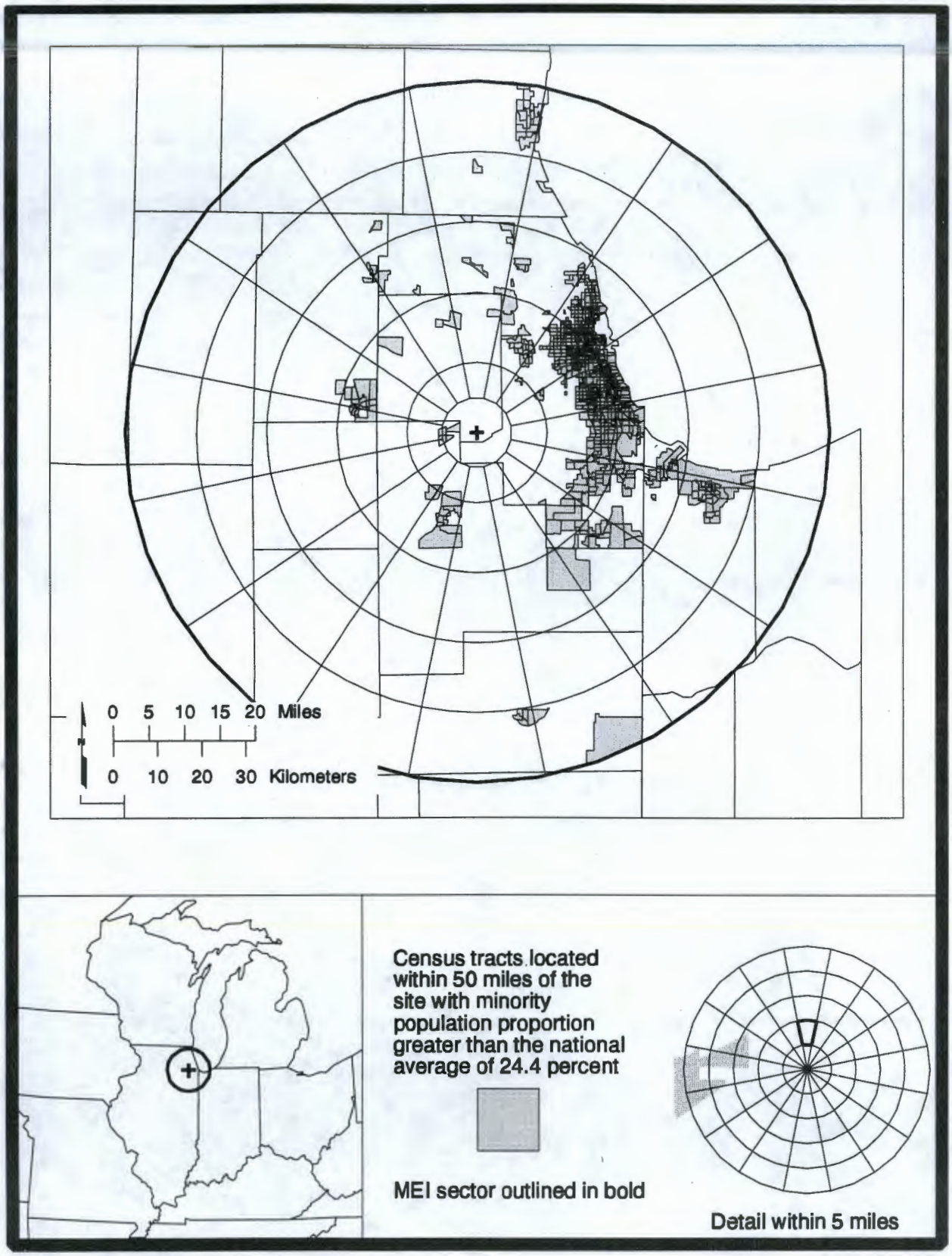


***Figure C.4–7. Distribution of Minority Populations at Argonne National Laboratory-East.***

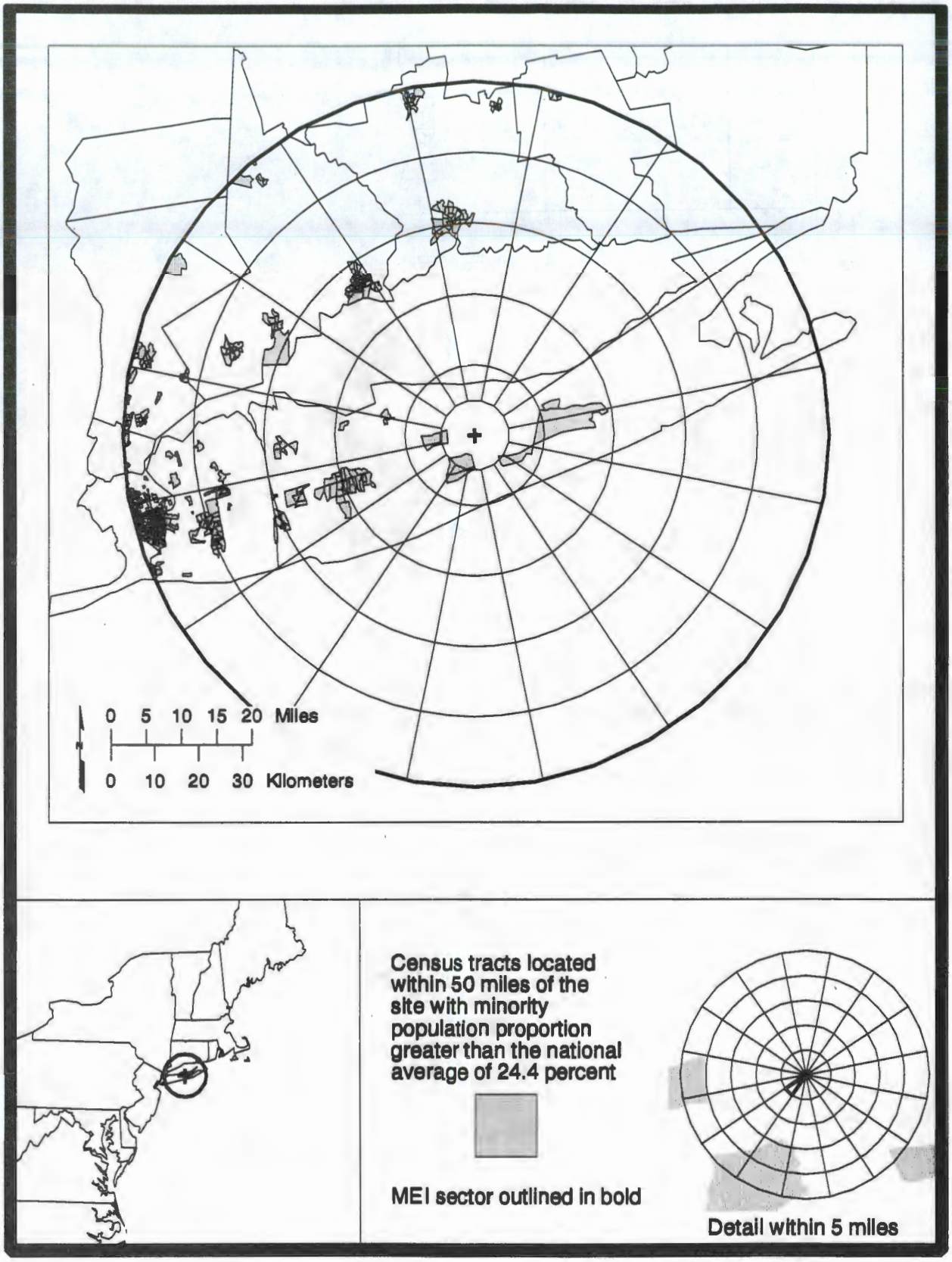


***Figure C.4–8. Distribution of Minority Populations at Brookhaven National Laboratory.***

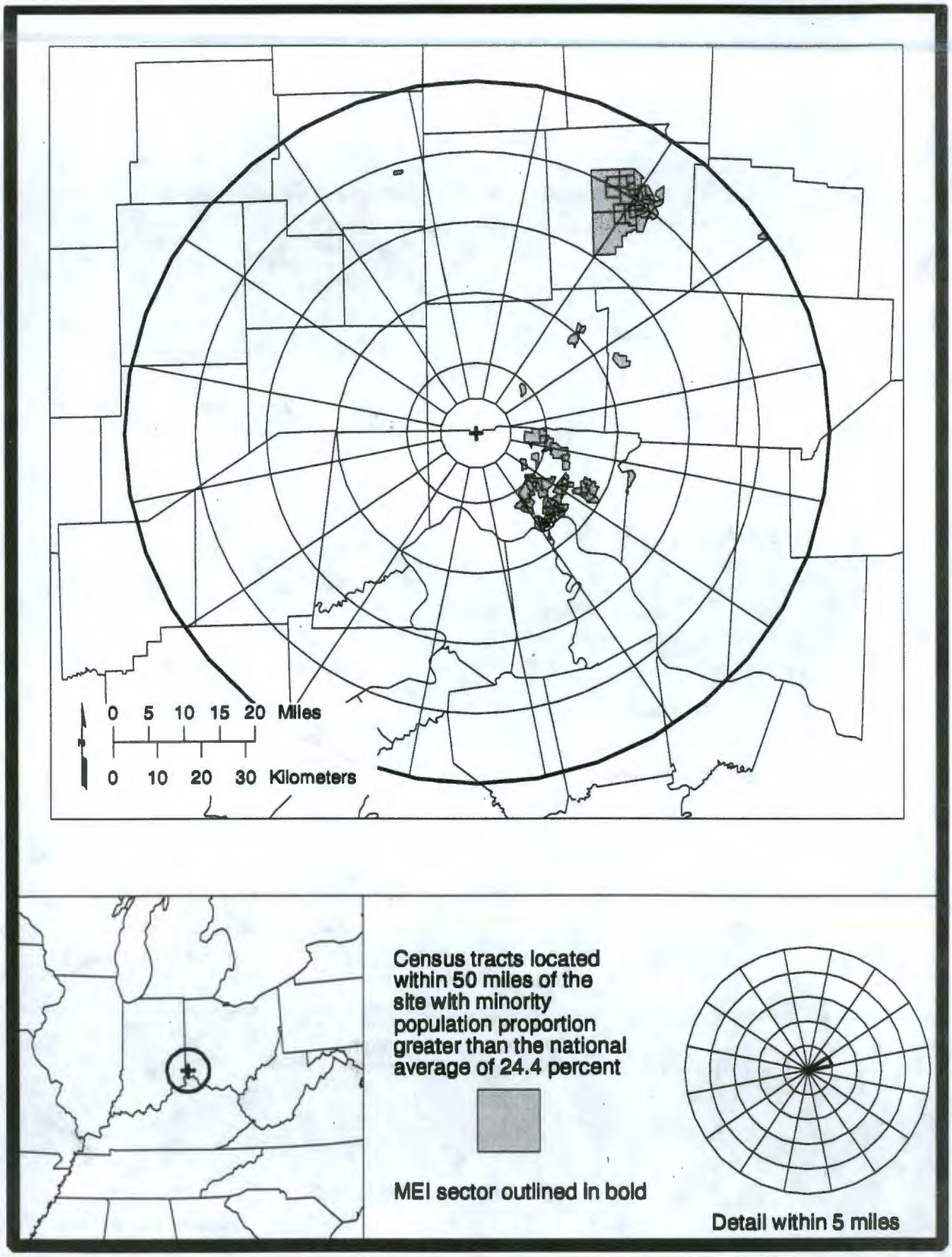


***Figure C.4–9. Distribution of Minority Populations at Fernald Environmental Management Project.***

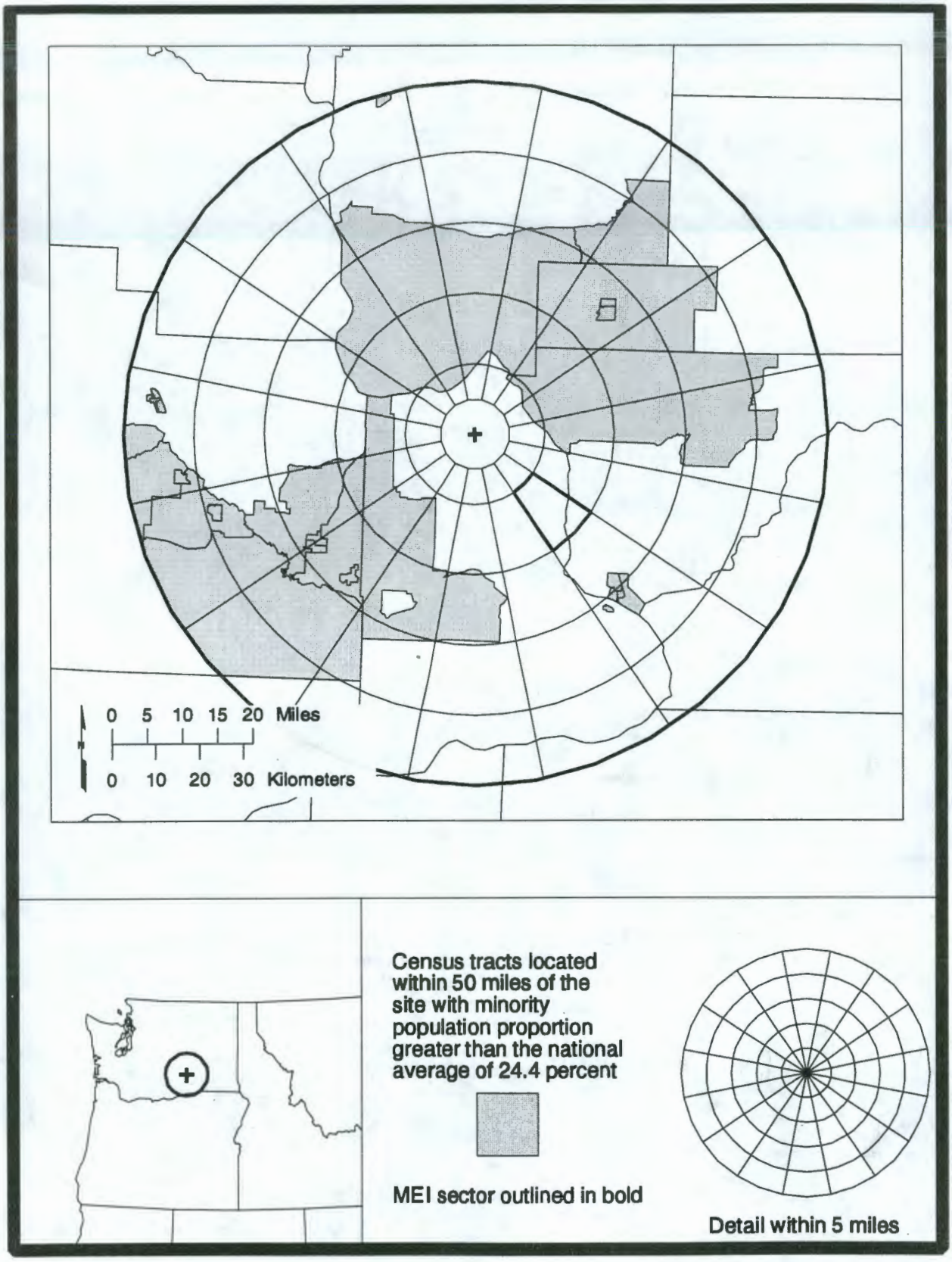


*Figure C.4–10a. Distribution of Minority Populations at the Hanford Site.*

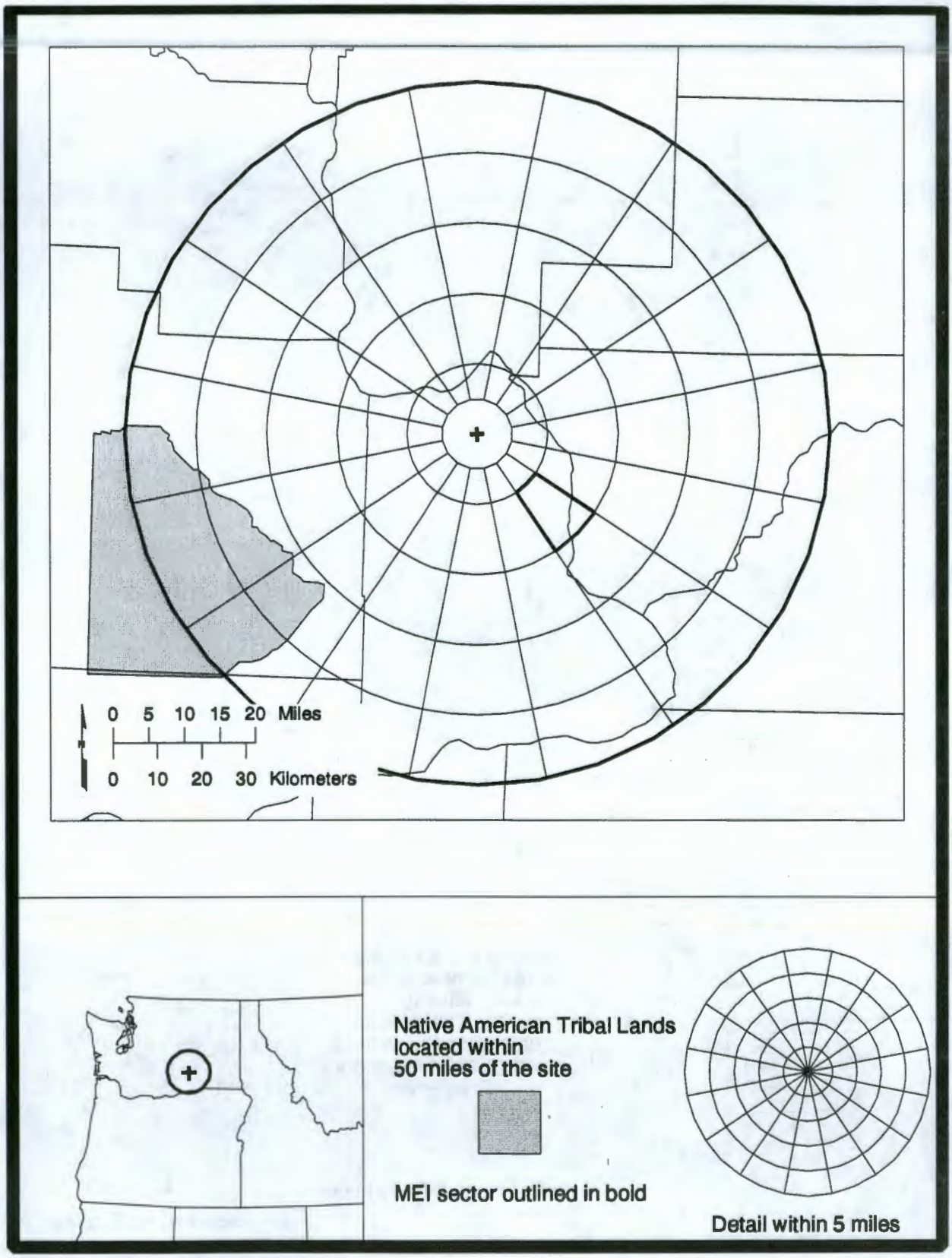


***Figure C.4–10b. Location of Tribal Lands at the Hanford Site.***

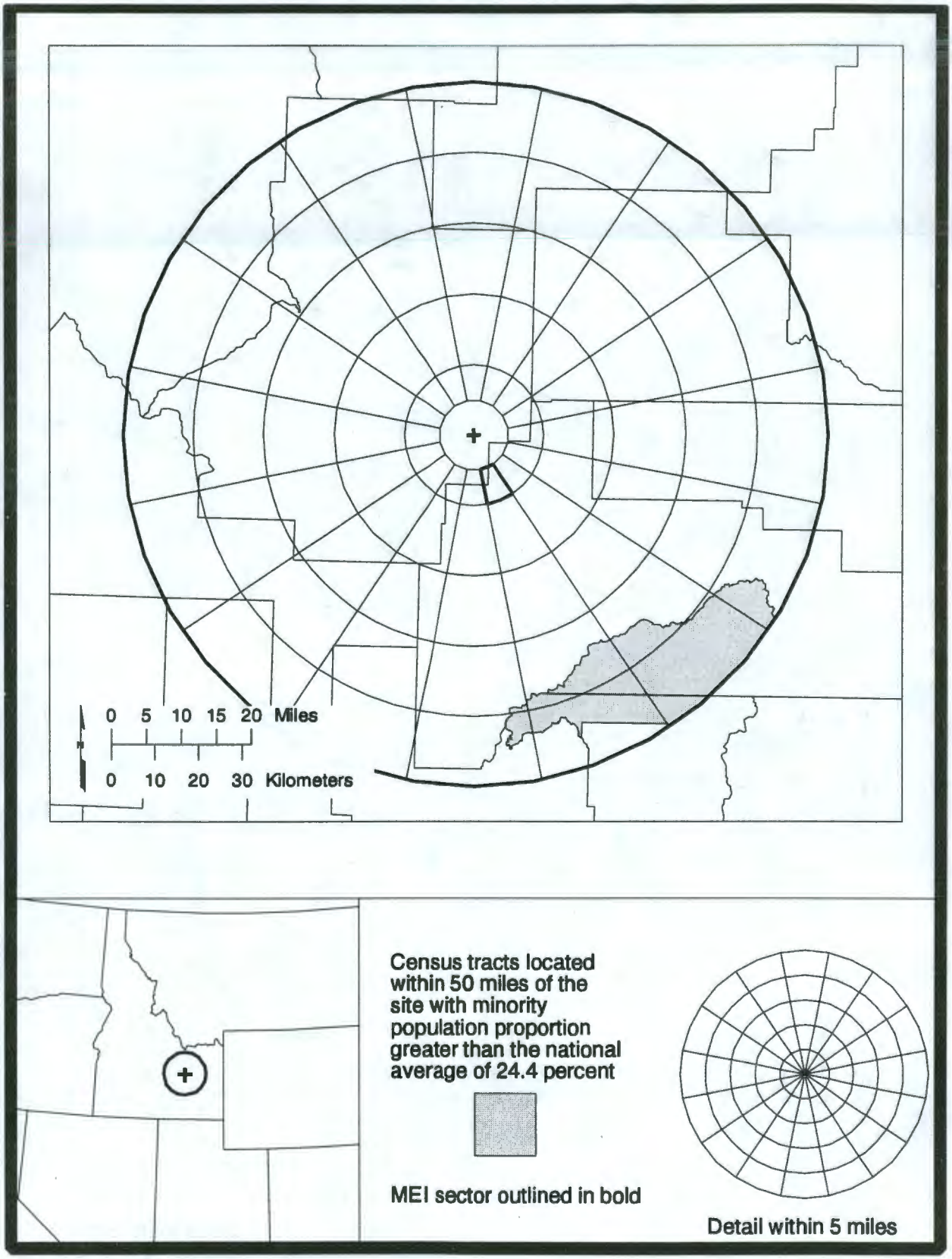


*Figure C.4–11a. Distribution of Minority Populations at Idaho National Engineering Laboratory.*

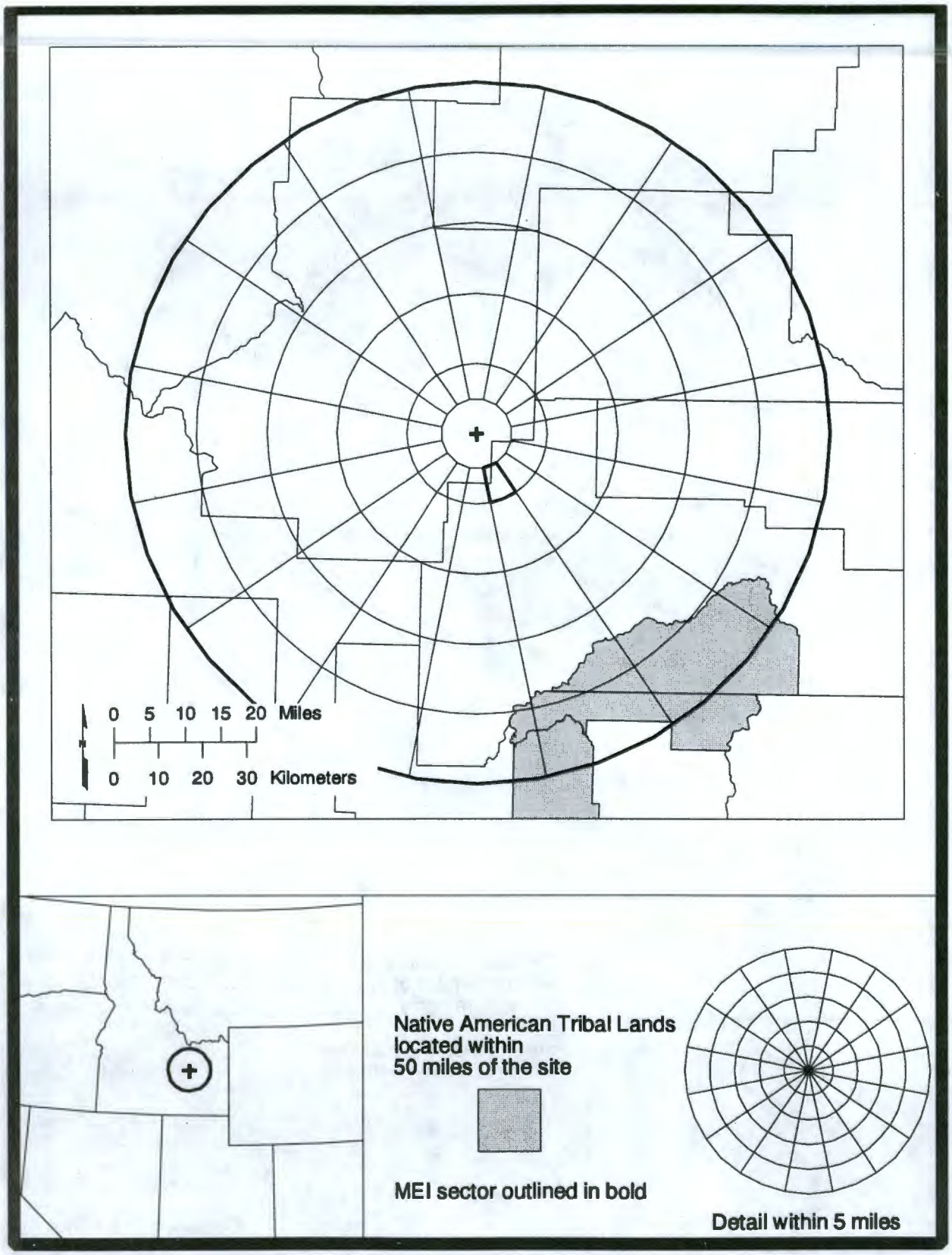


***Figure C.4–11b. Location of Tribal Lands at Idaho National Engineering Laboratory.***

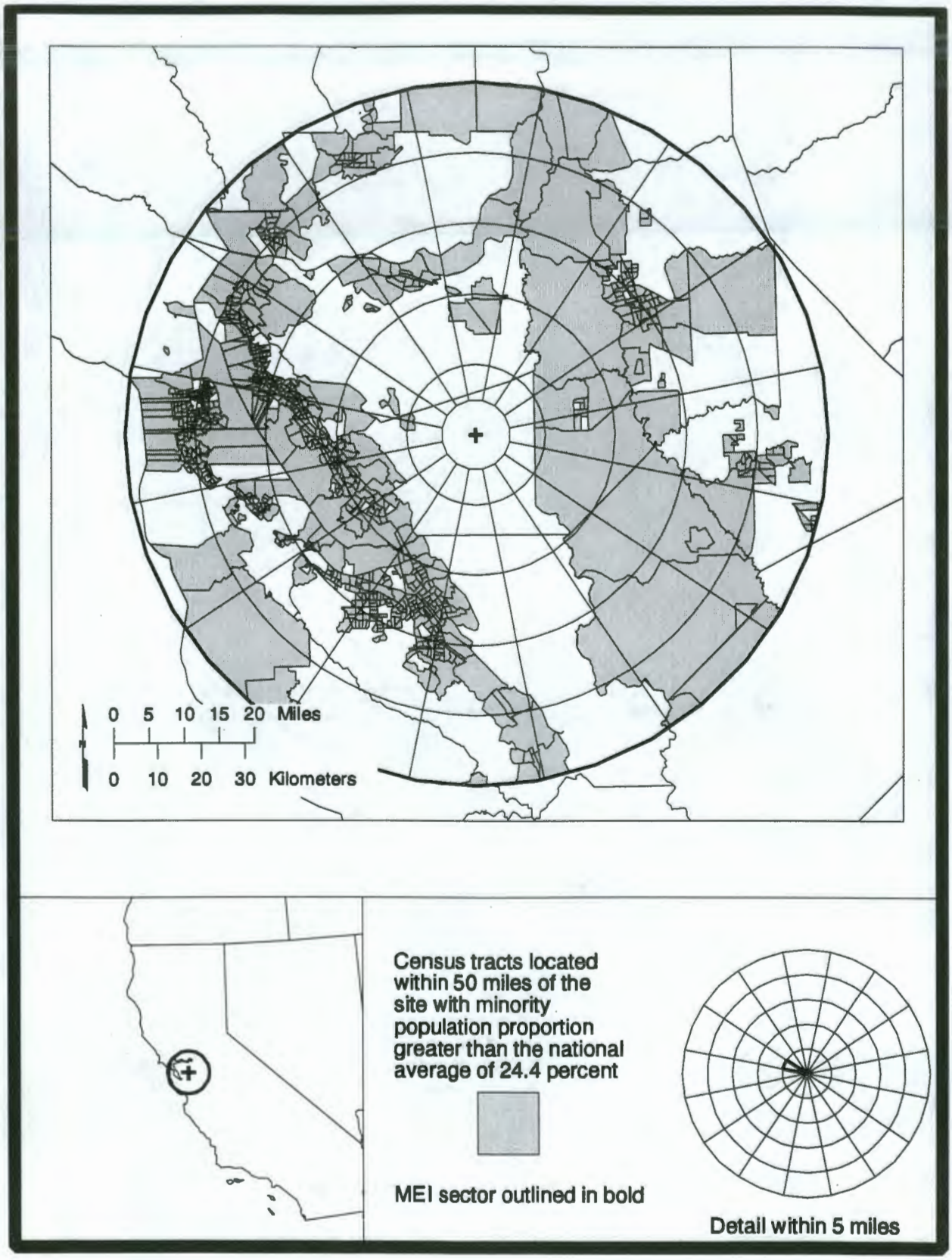


*Figure C.4–12. Distribution of Minority Populations at Lawrence Livermore National Laboratory.*

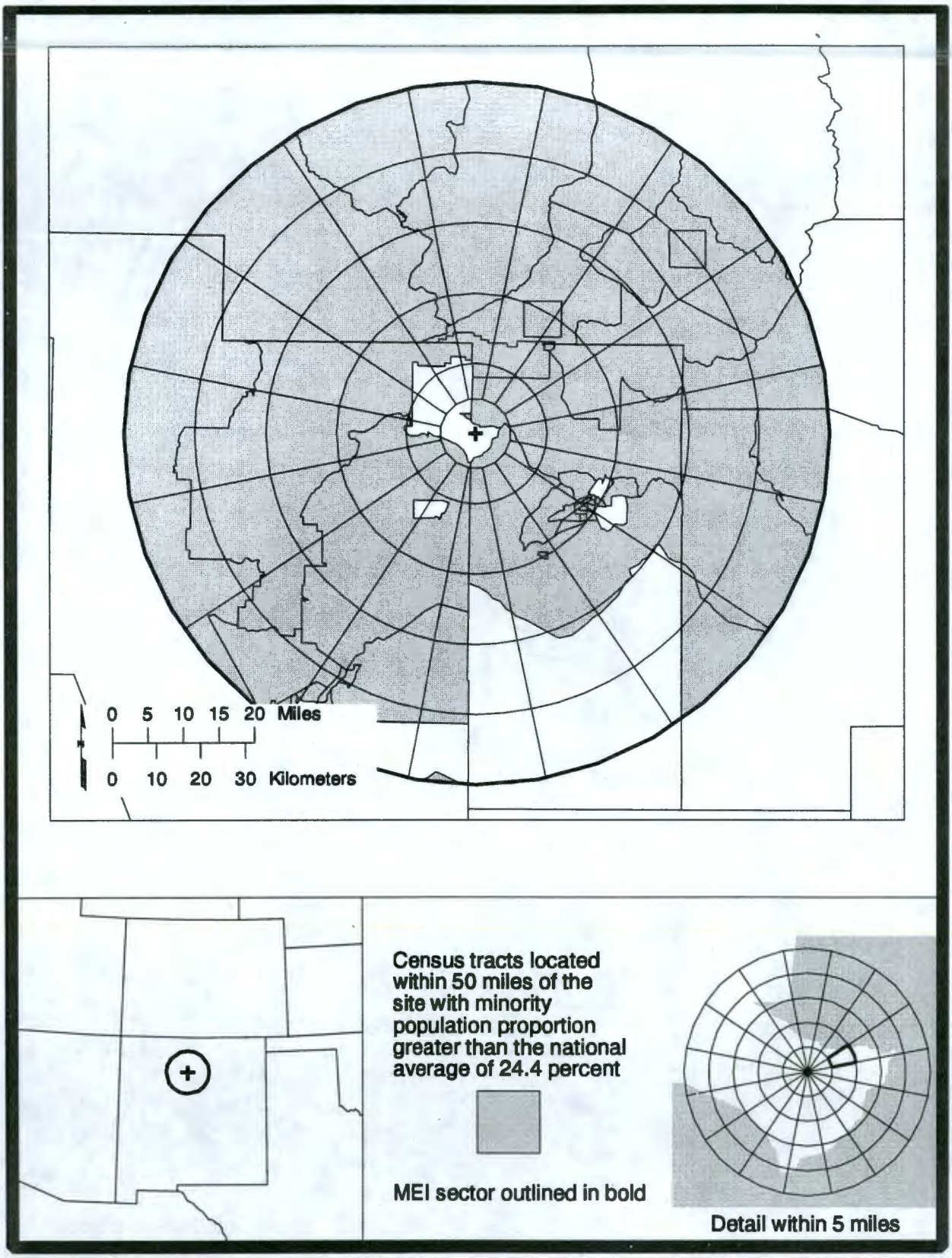


***Figure C.4–13a. Distribution of Minority Populations at Los Alamos National Laboratory.***

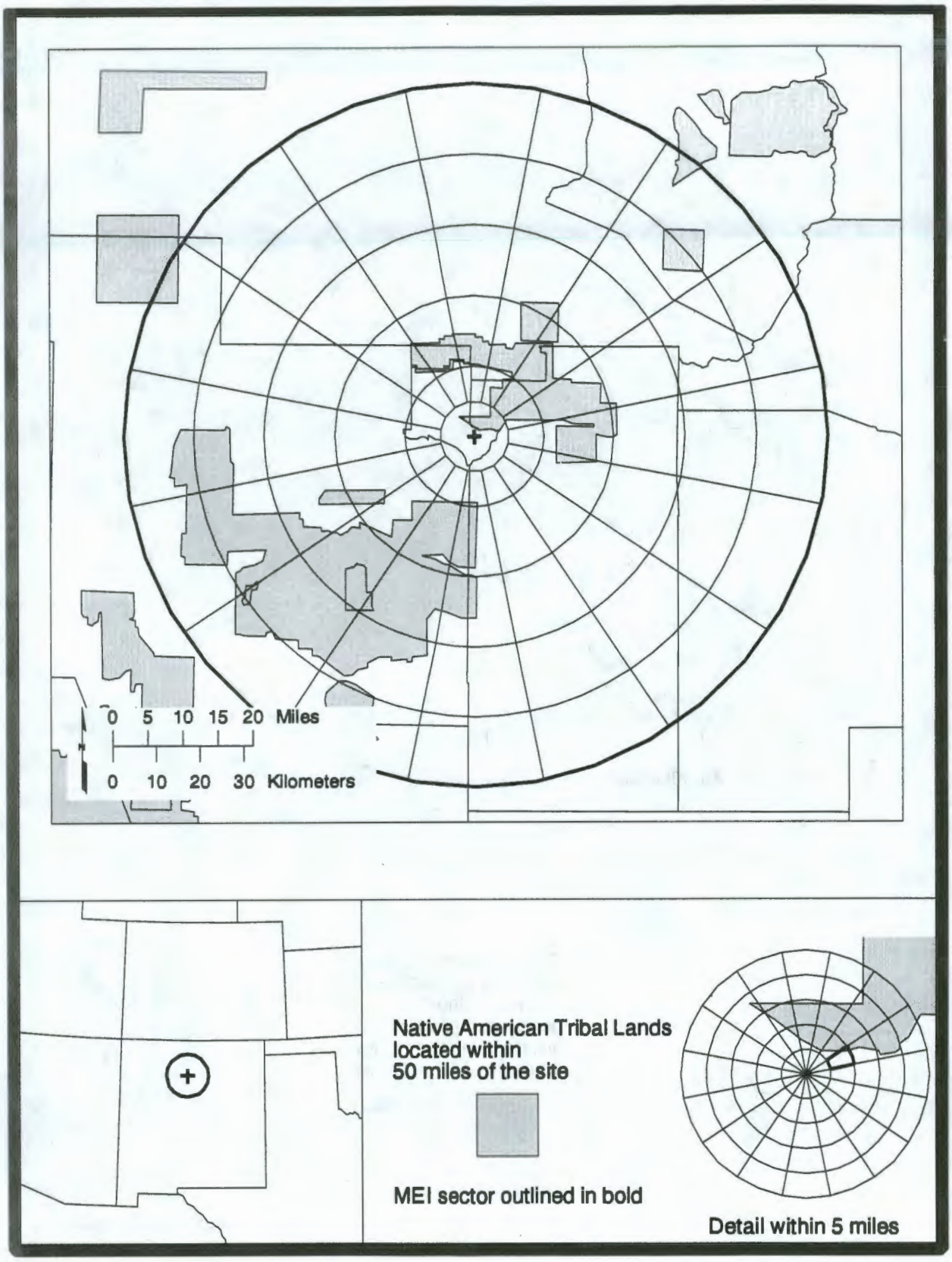


*Figure C.4–13b. Locations of Tribal Lands at Los Alamos National Laboratory.*

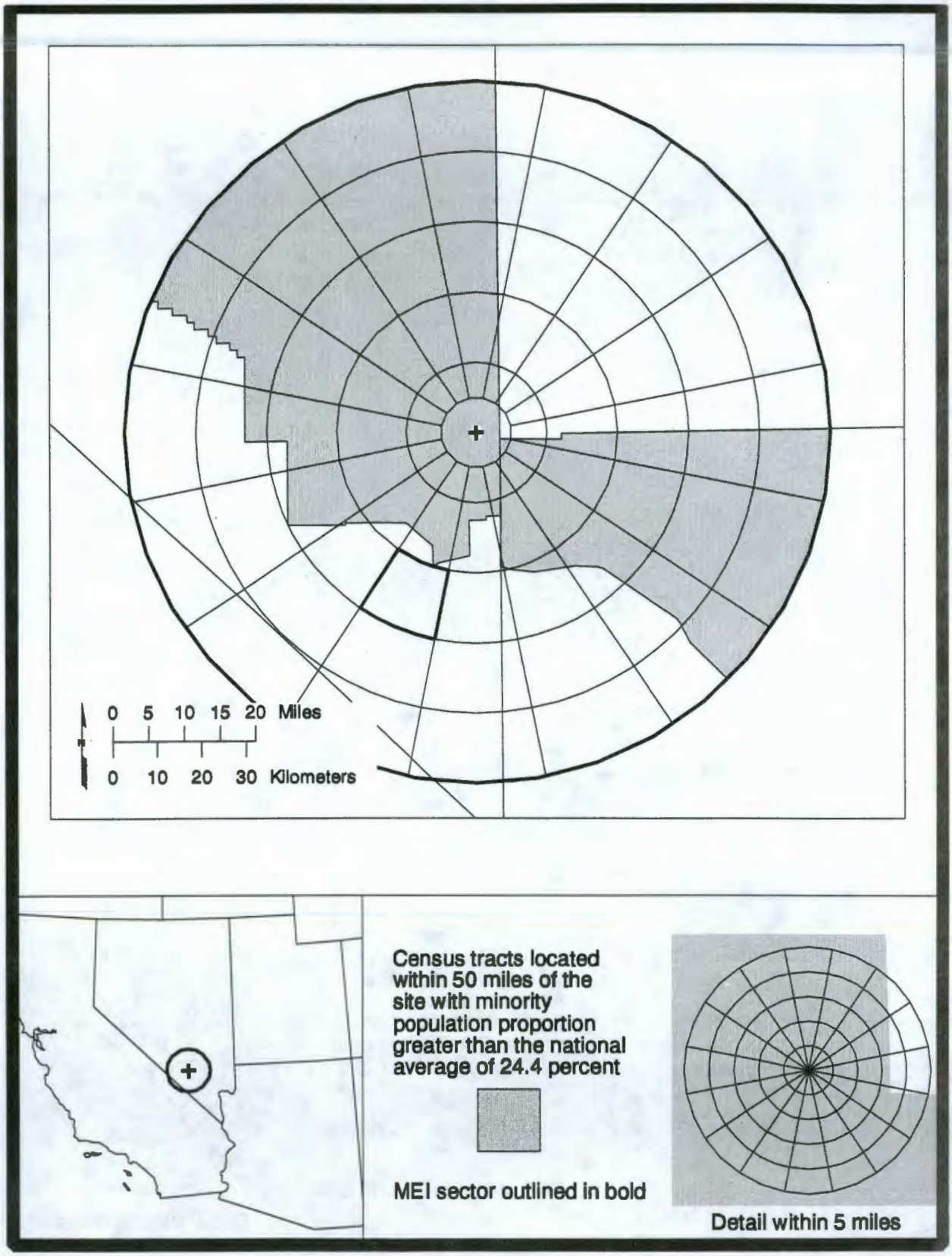


***Figure C.4–14. Distribution of Minority Populations at the Nevada Test Site.***

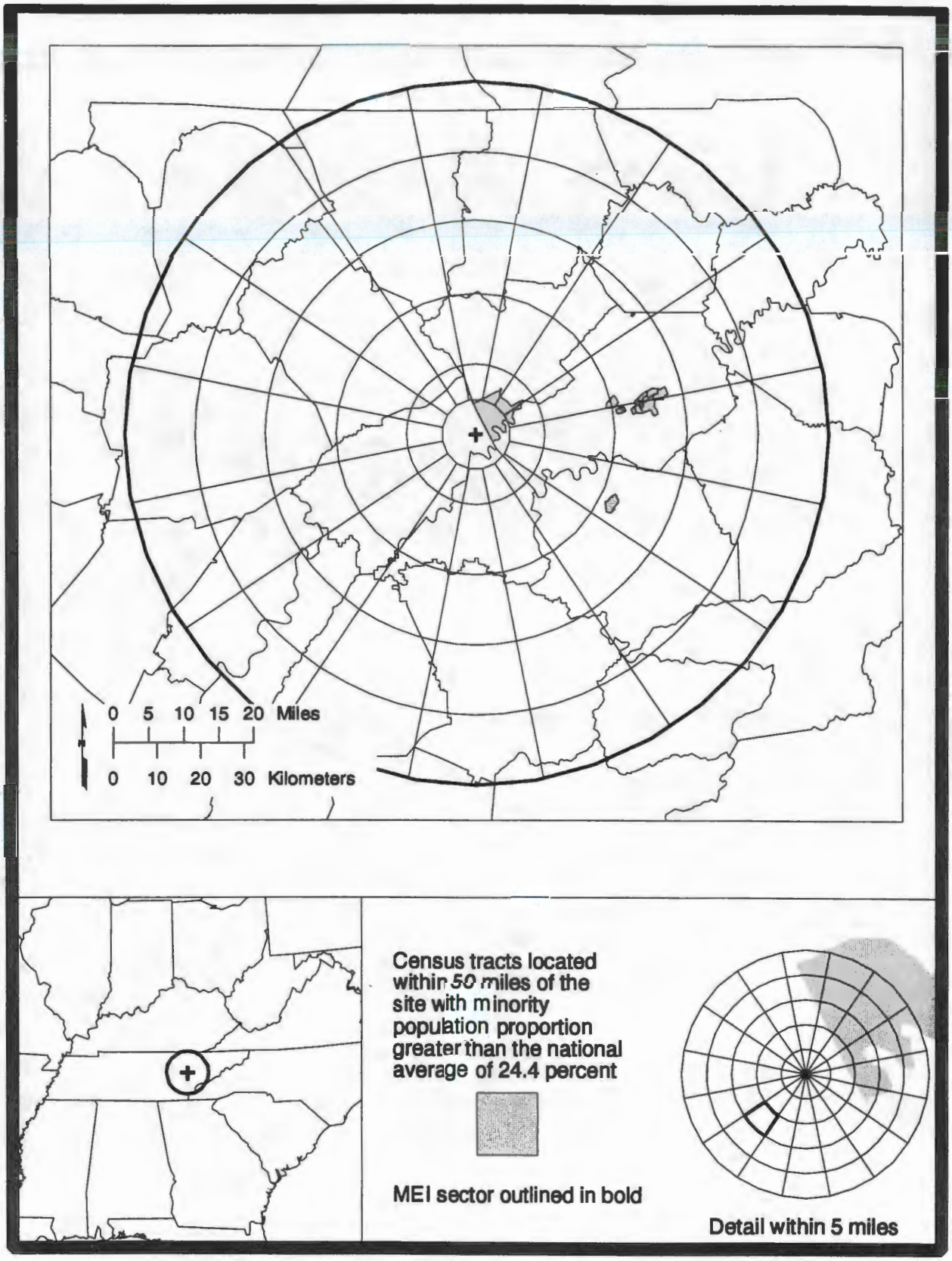


*Figure C.4–15. Distribution of Minority Populations at the Oak Ridge Reservation.*

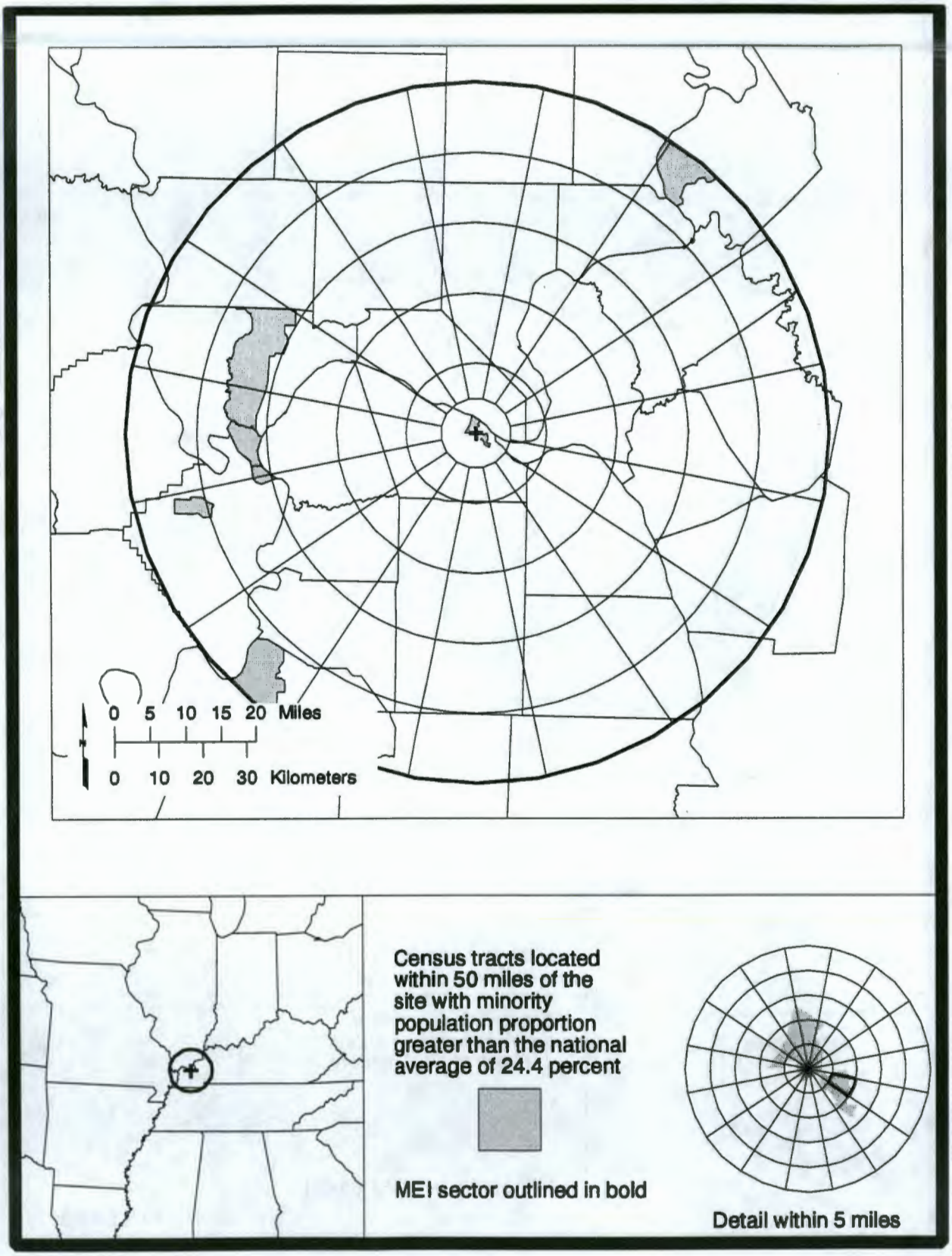


***Figure C.4–16. Distribution of Minority Populations at the Paducah Gaseous Diffusion Plant.***

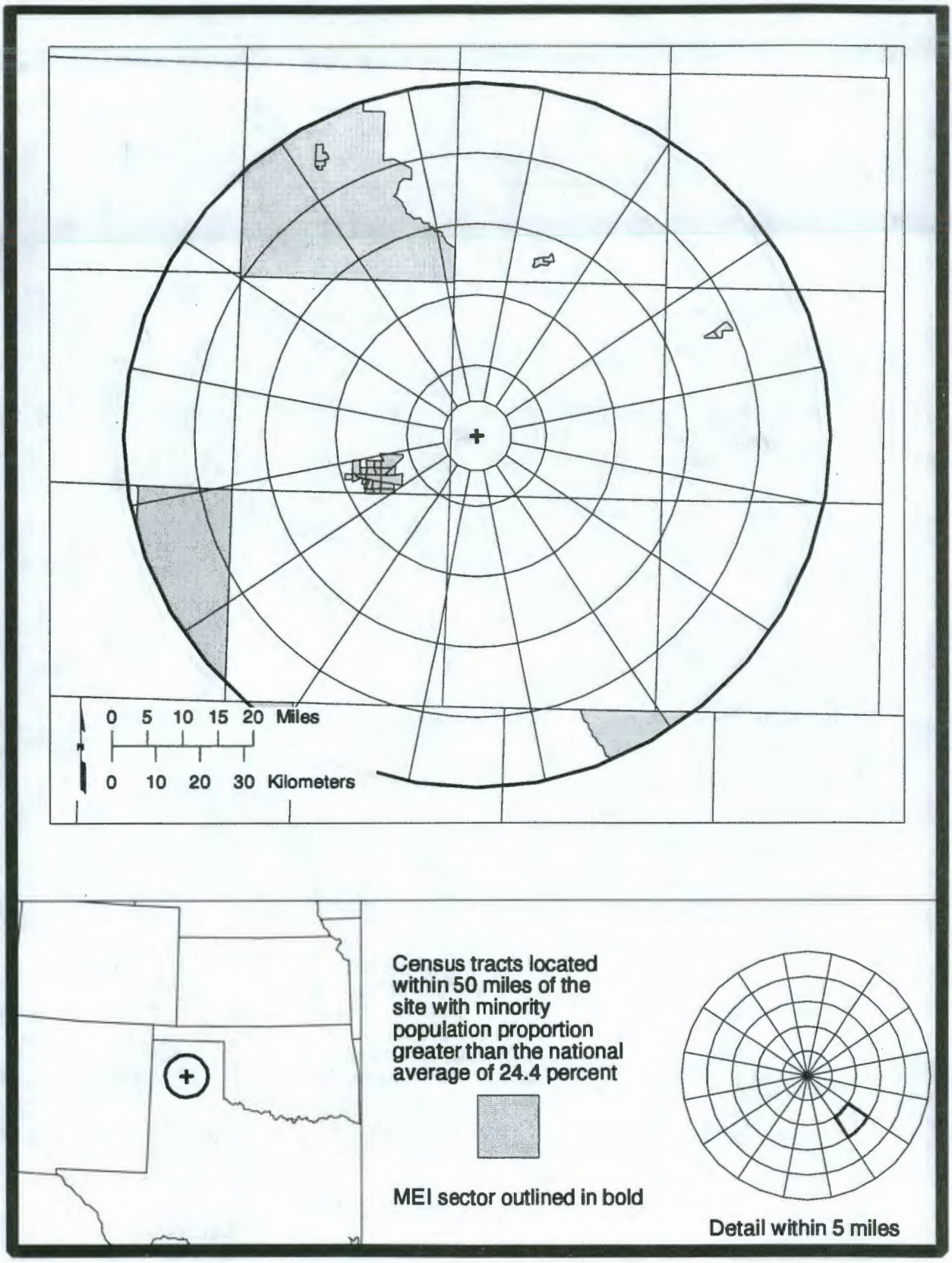


*Figure C.4–17. Distribution of Minority Populations at the Pantex Plant.*

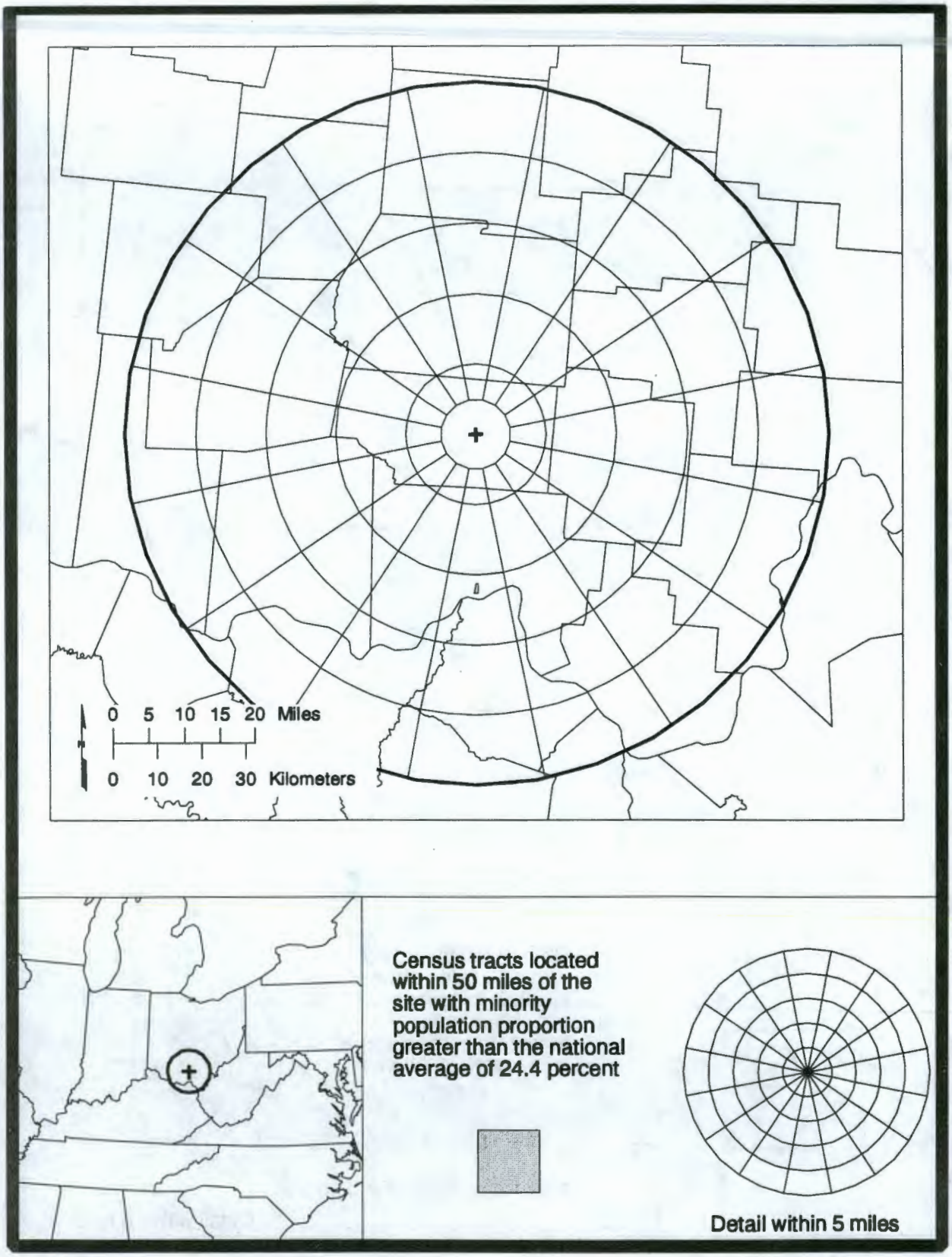


***Figure C.4–18. Distribution of Minority Populations at the Portsmouth Gaseous Diffusion Plant.***

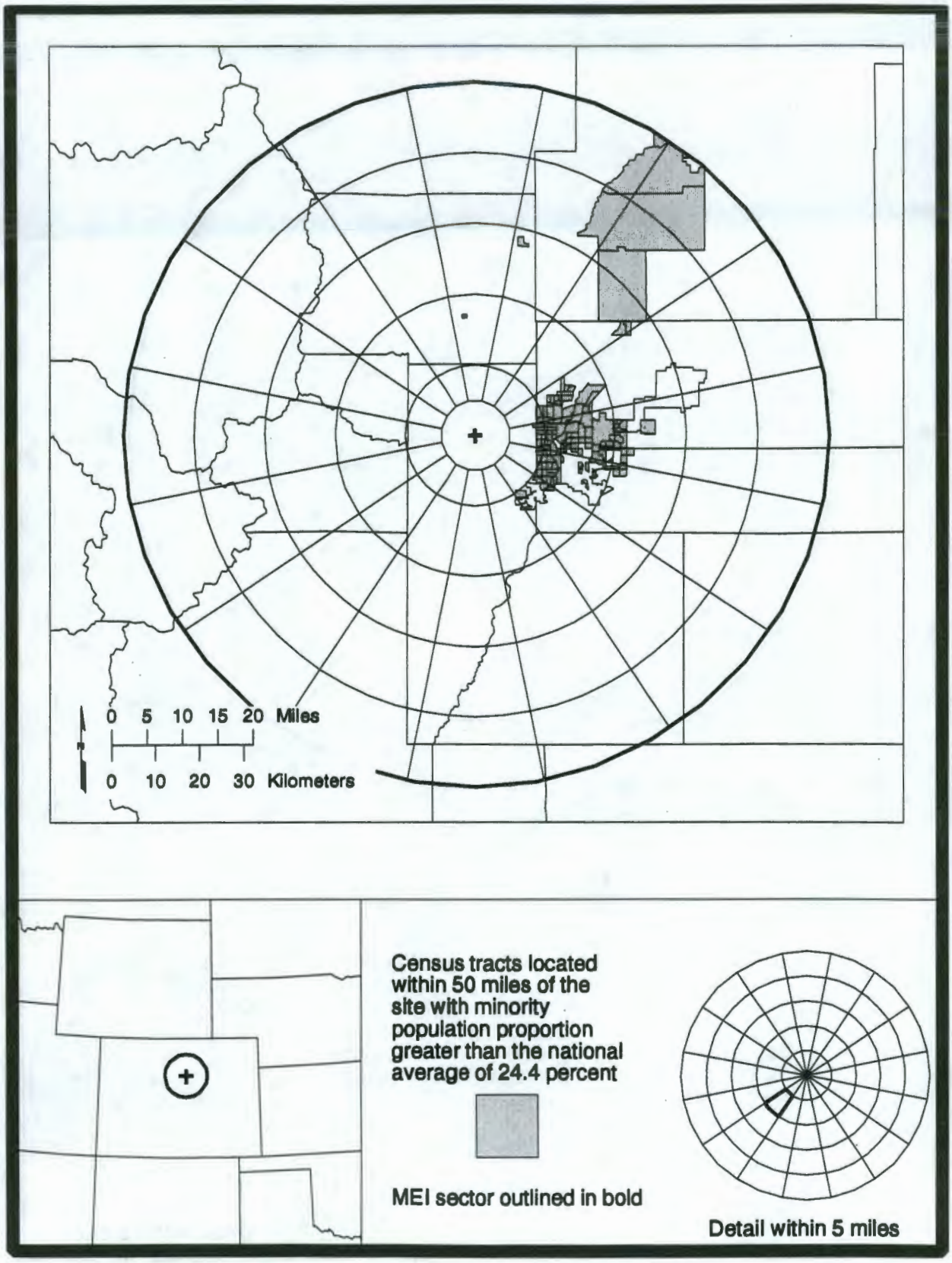


***Figure C.4–19. Distribution of Minority Populations at Rocky Flats Environmental Technology Site.***

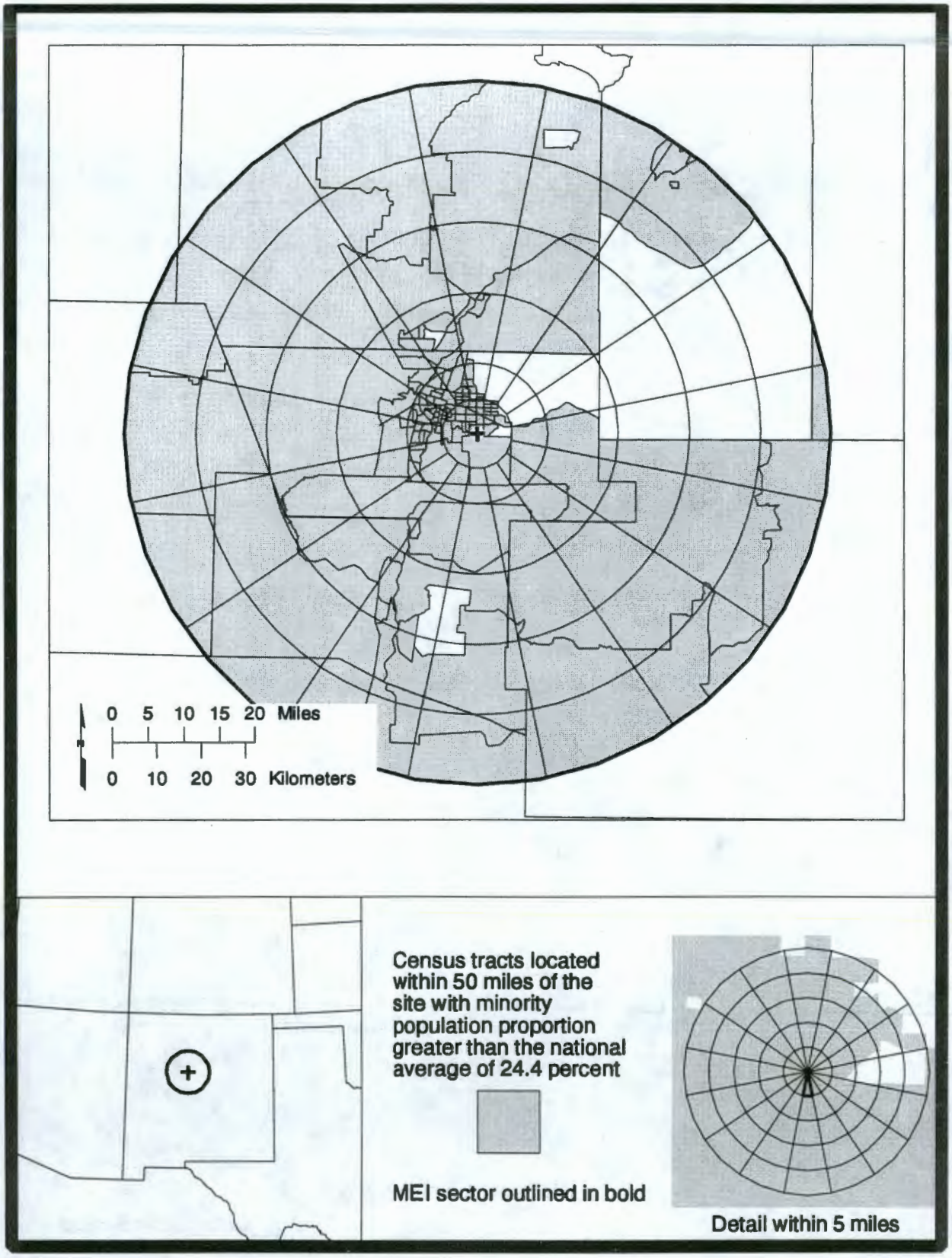


***Figure C.4–20a. Distribution of Minority Populations at Sandia National Laboratories-New Mexico.***

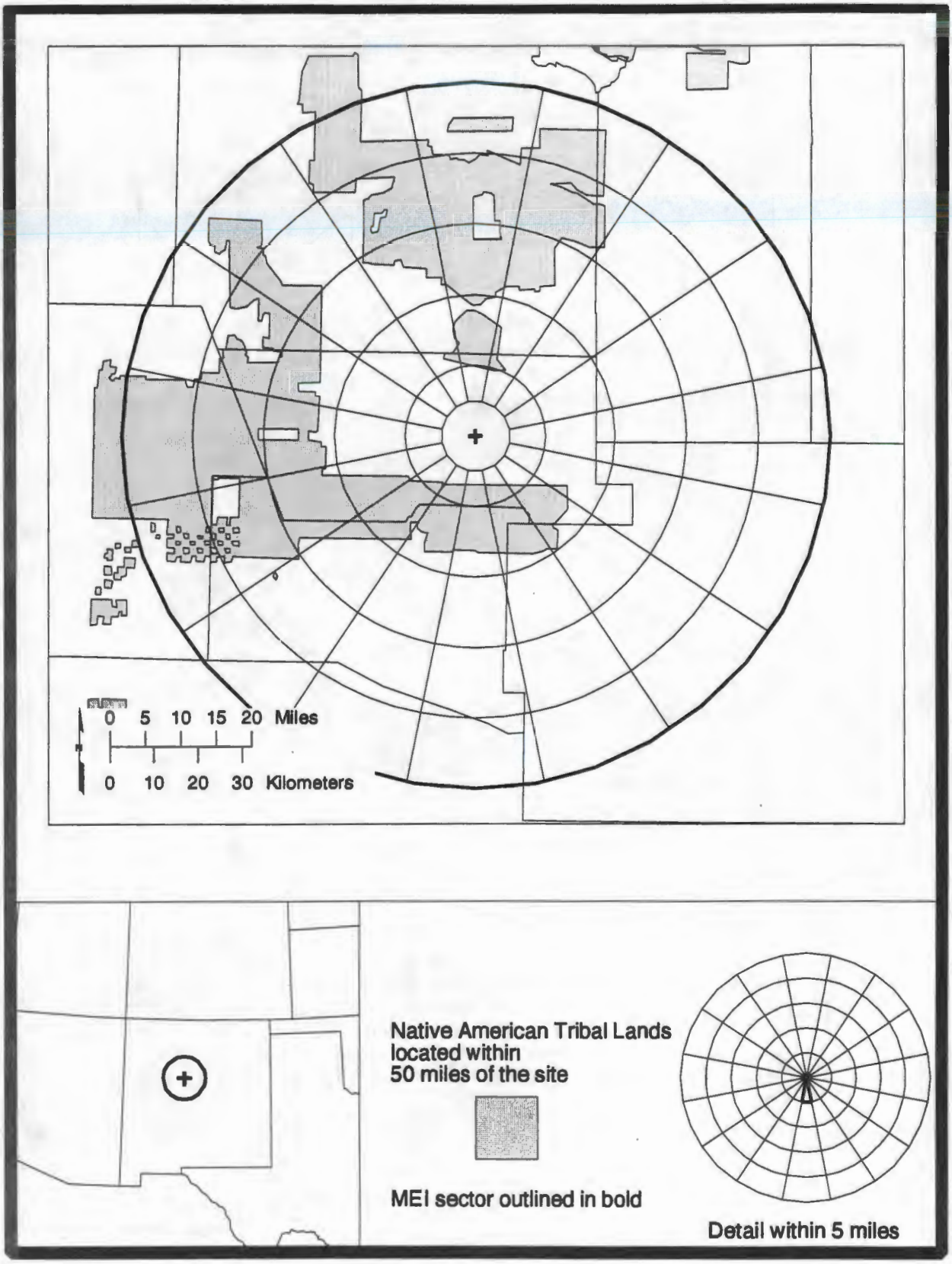


***Figure C.4–20b. Locations of Tribal Lands at Sandia National Laboratories-New Mexico.***

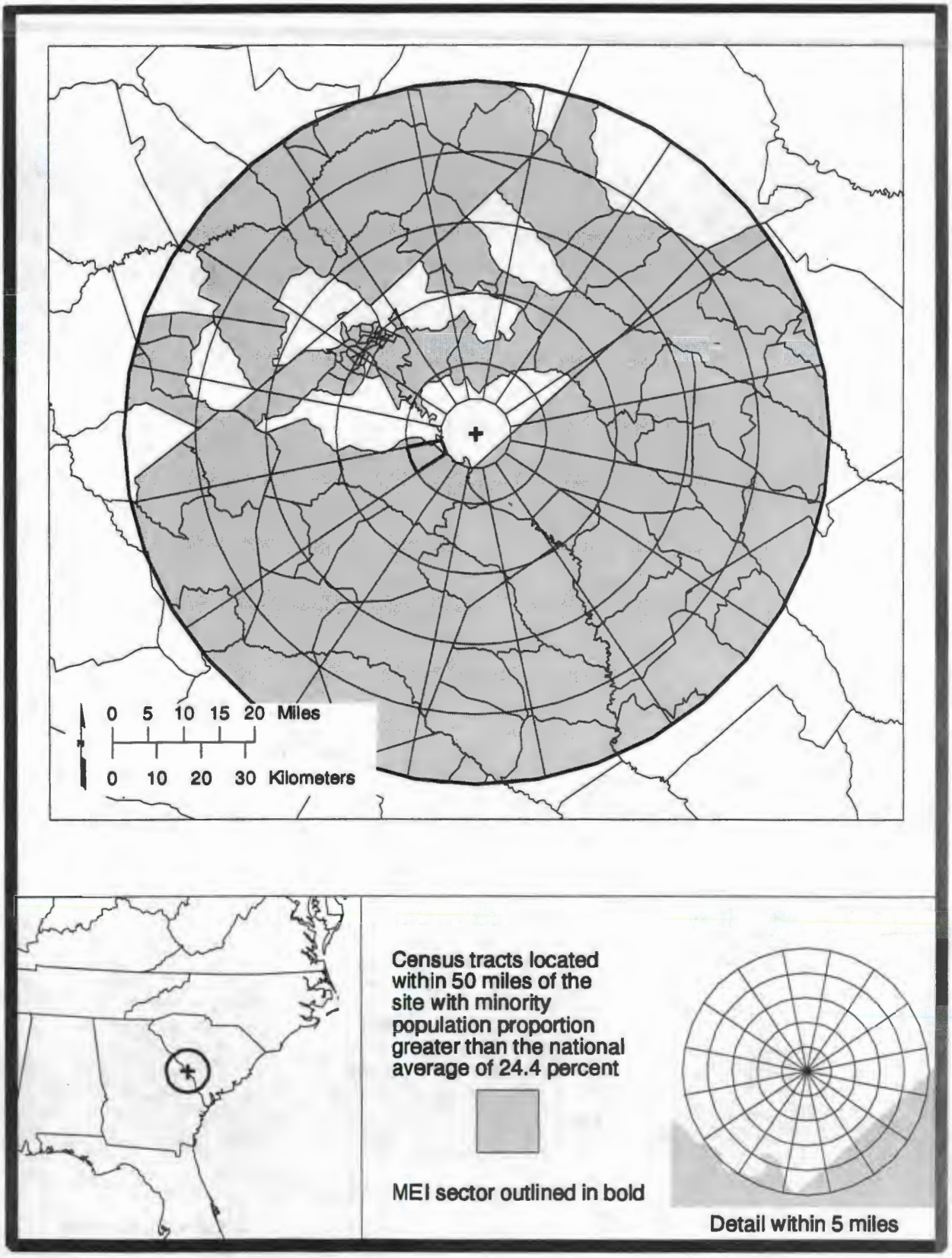


***Figure C.4–21. Distribution of Minority Populations at the Savannah River Site.***

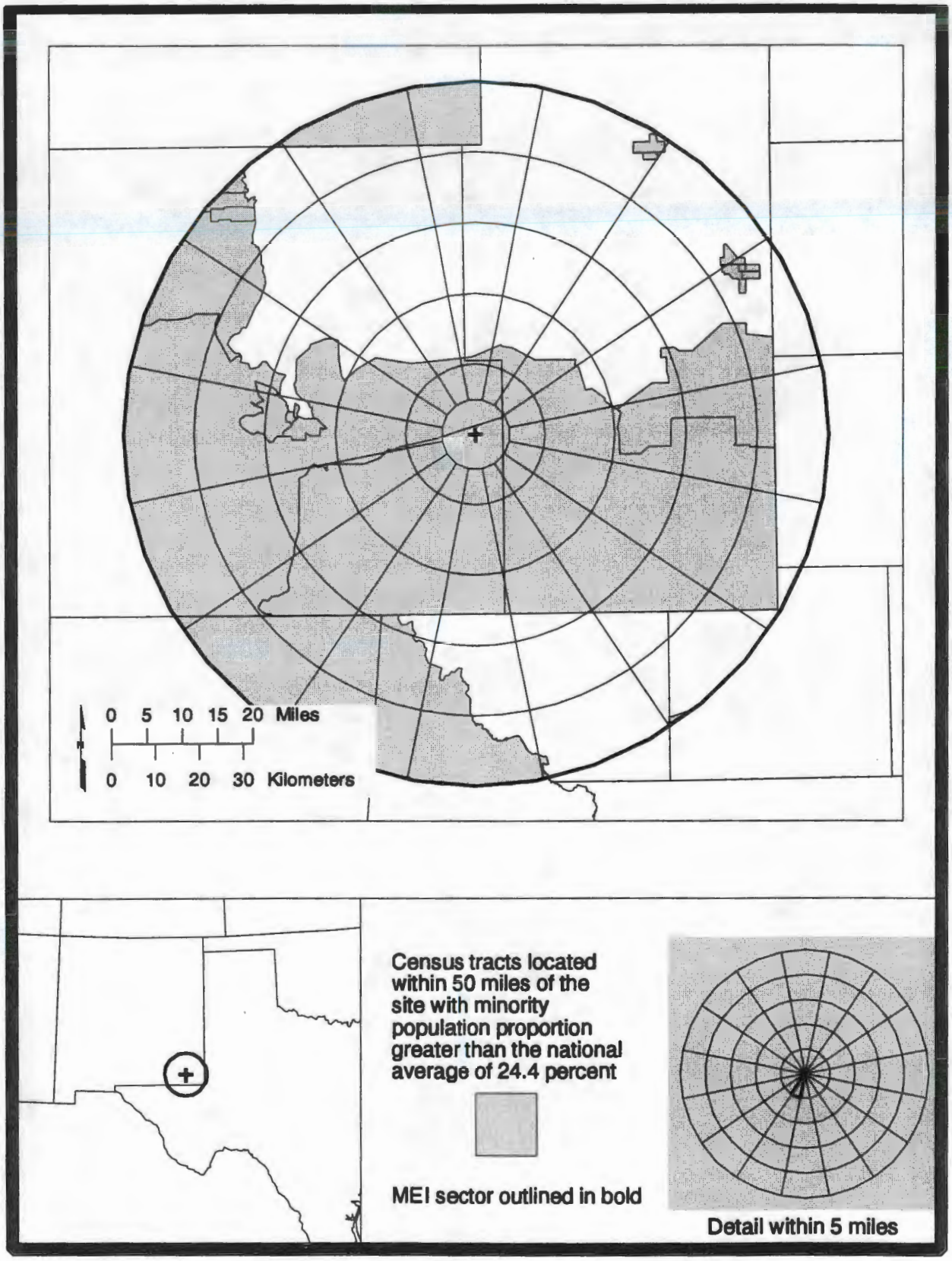


***Figure C.4–22. Distribution of Minority Populations at the Waste Isolation Pilot Plant.***

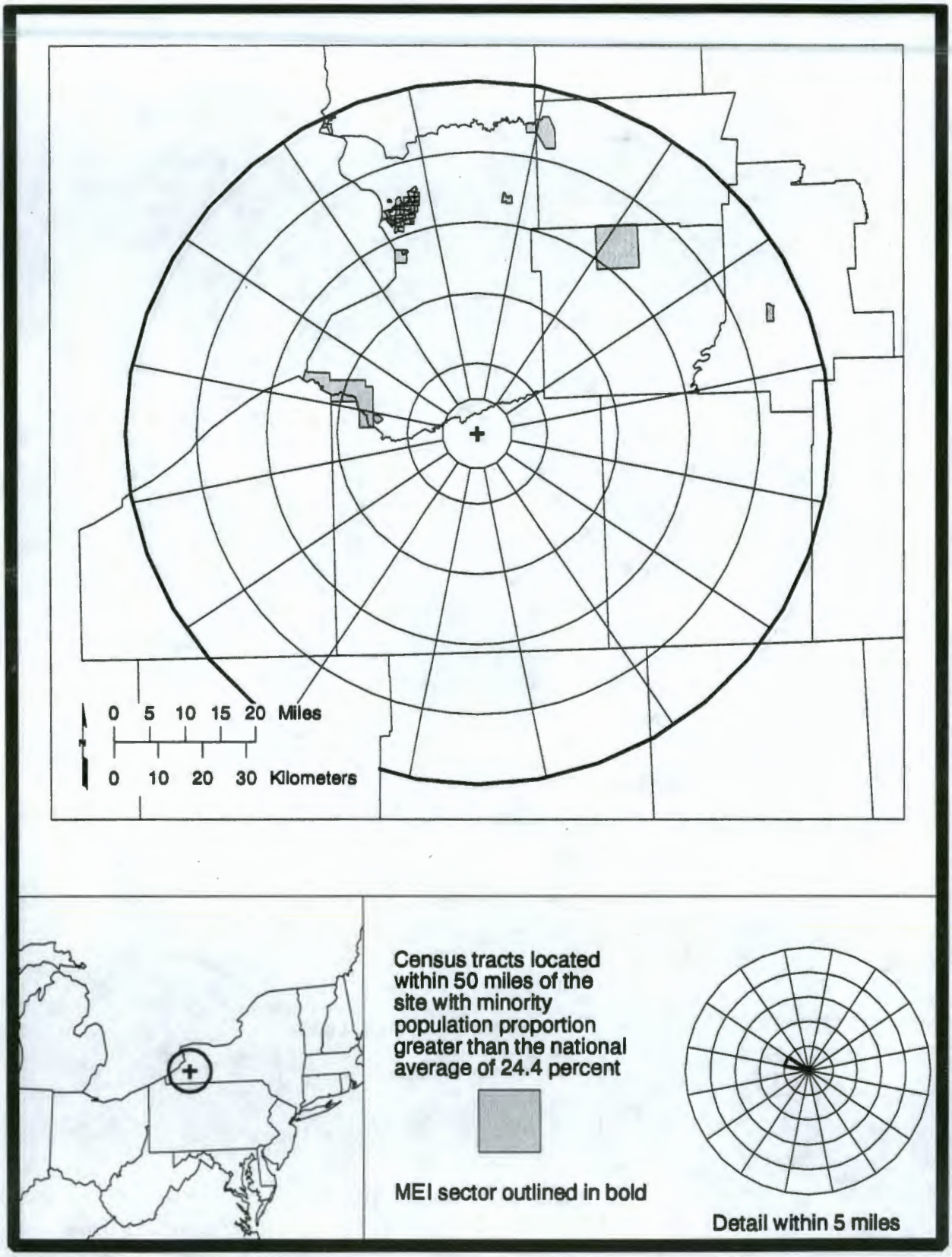


***Figure C.4-23a. Distribution of Minority Populations at the West Valley Demonstration Plant.***

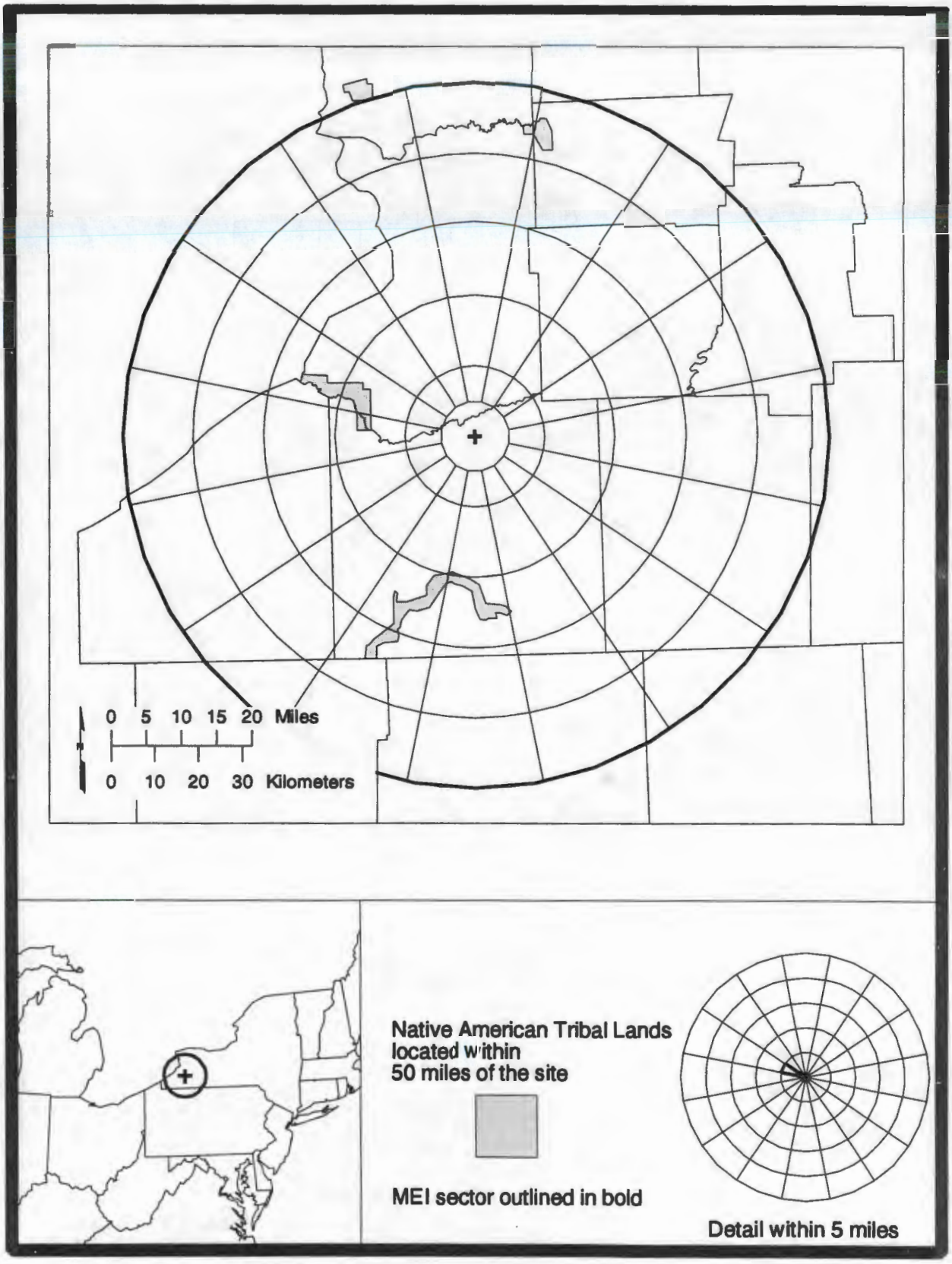


***Figure C.4–23b. Locations of Tribal Lands at the West Valley Demonstration Project.***

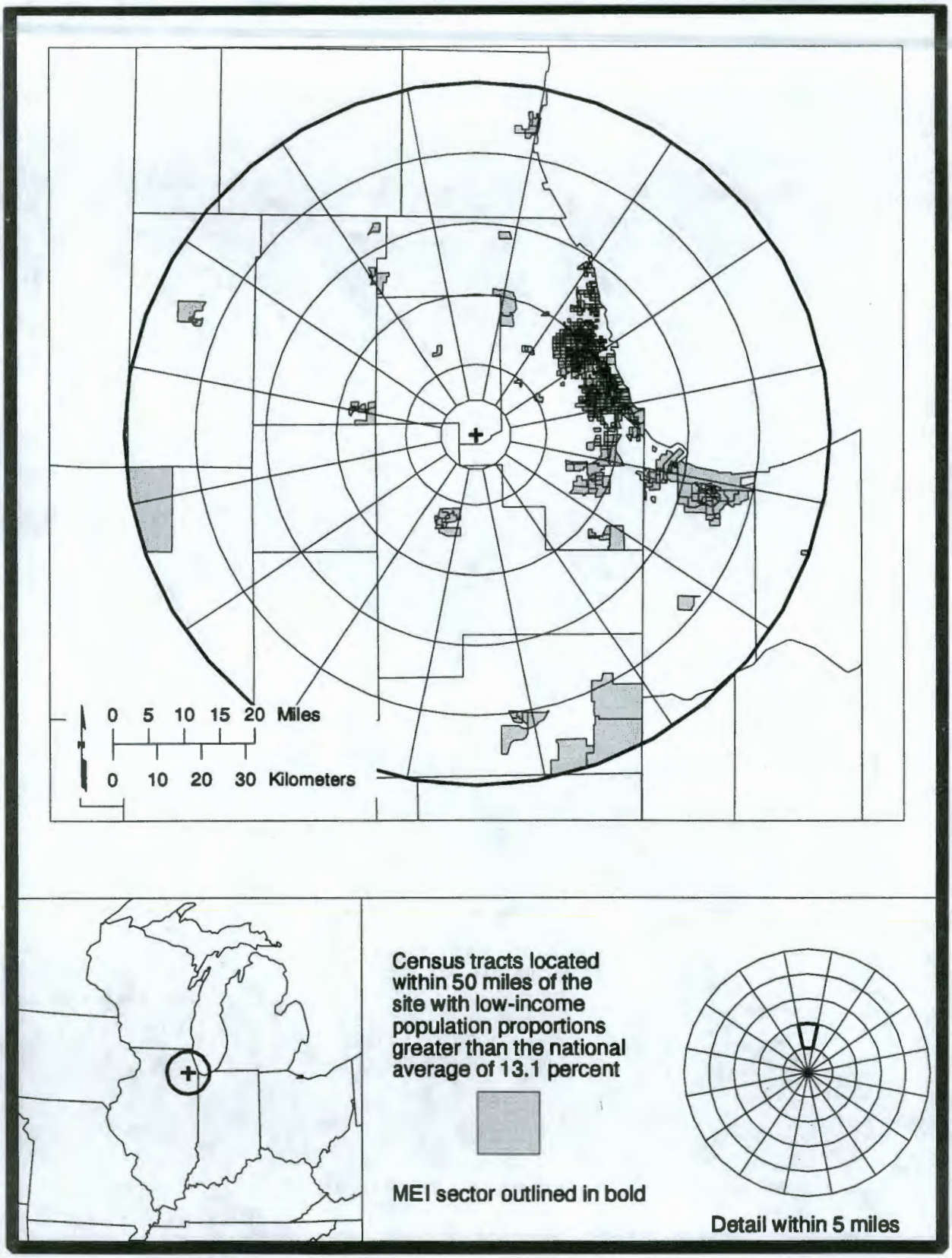


***Figure C.4–24. Distribution of Low-Income Populations at Argonne National Laboratory-East.***

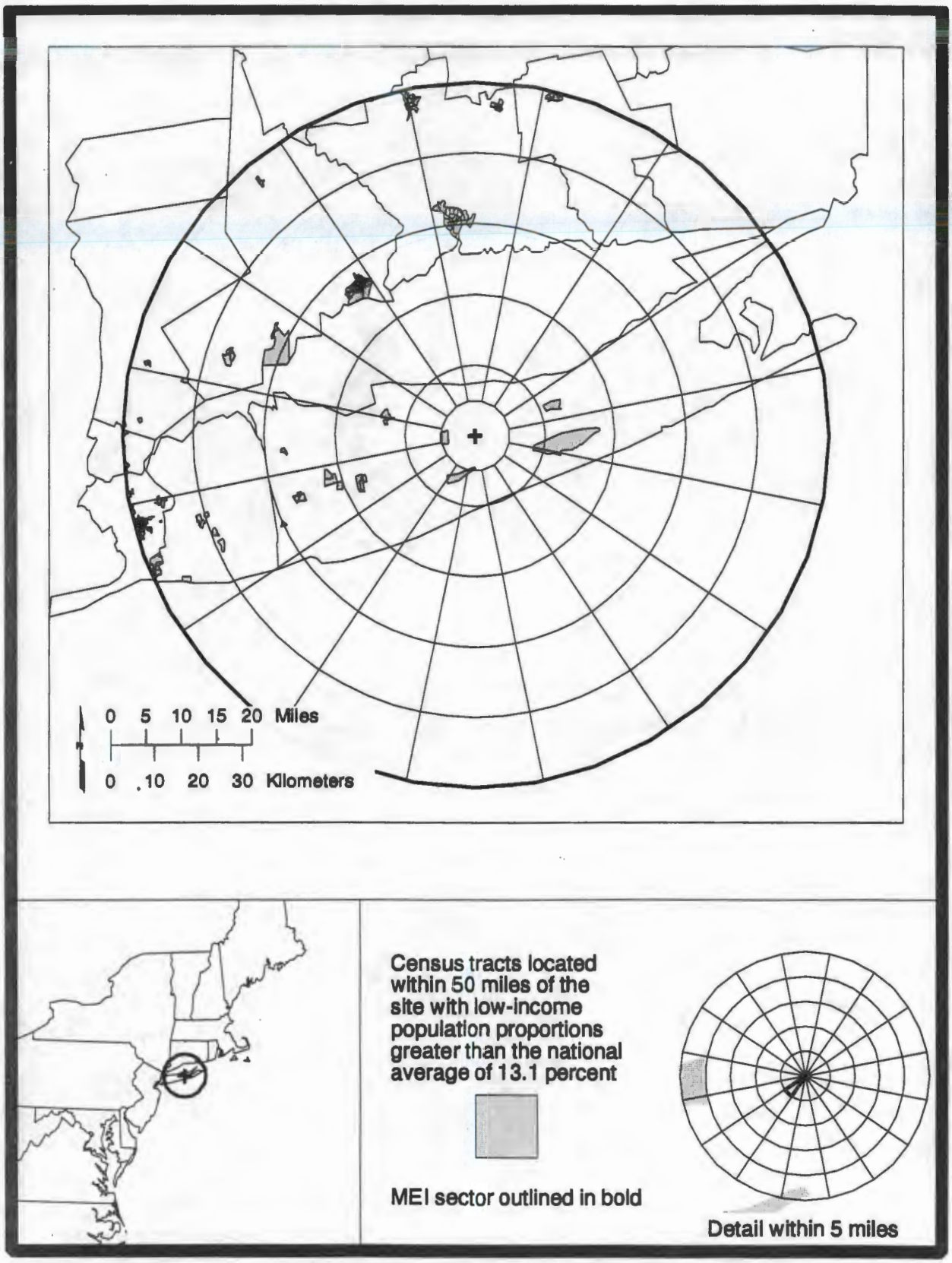


***Figure C.4–25. Distribution of Low-Income Populations at Brookhaven National Laboratory.***

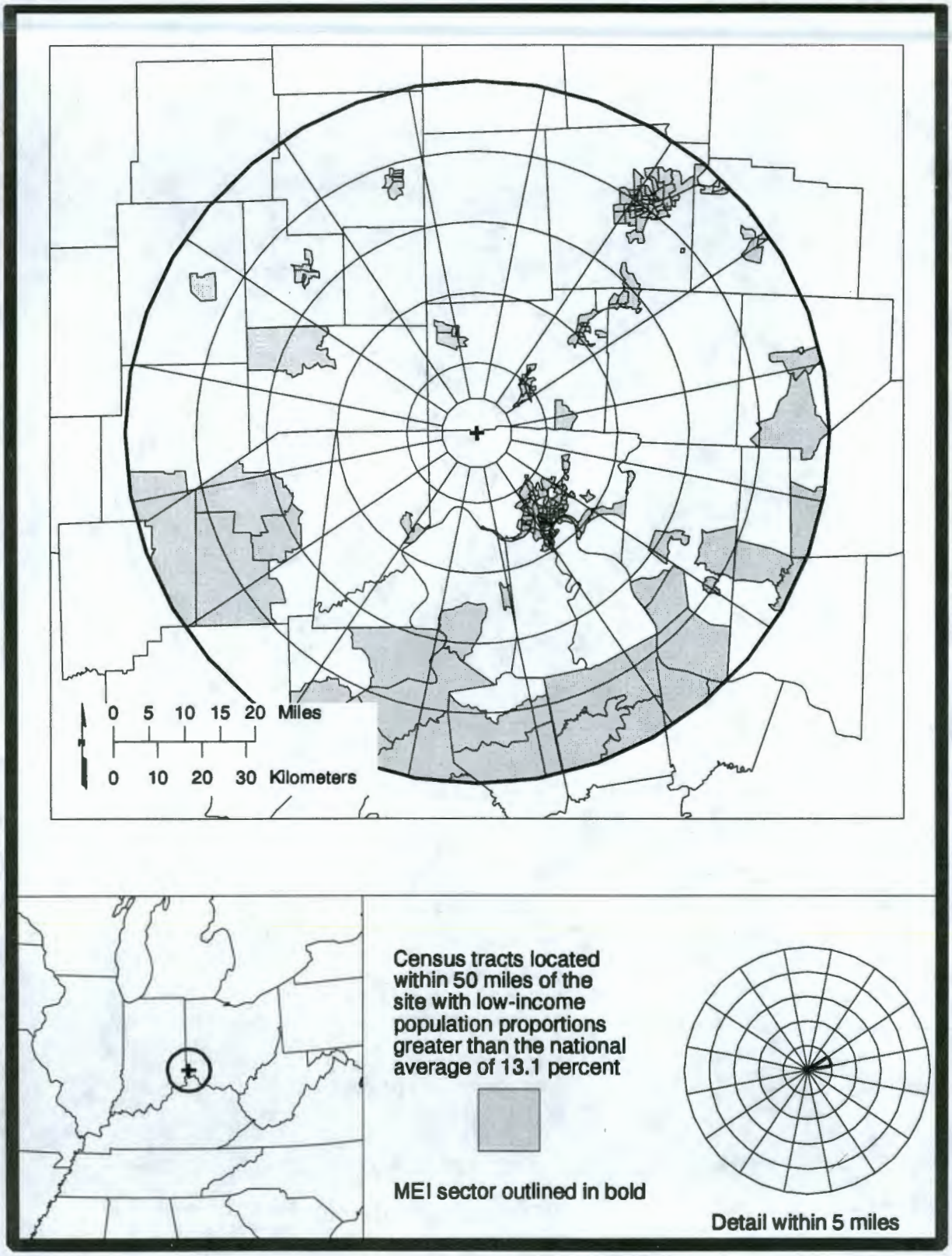


***Figure C.4–26. Distribution of Low-Income Populations at Fernald Environmental Management Project.***

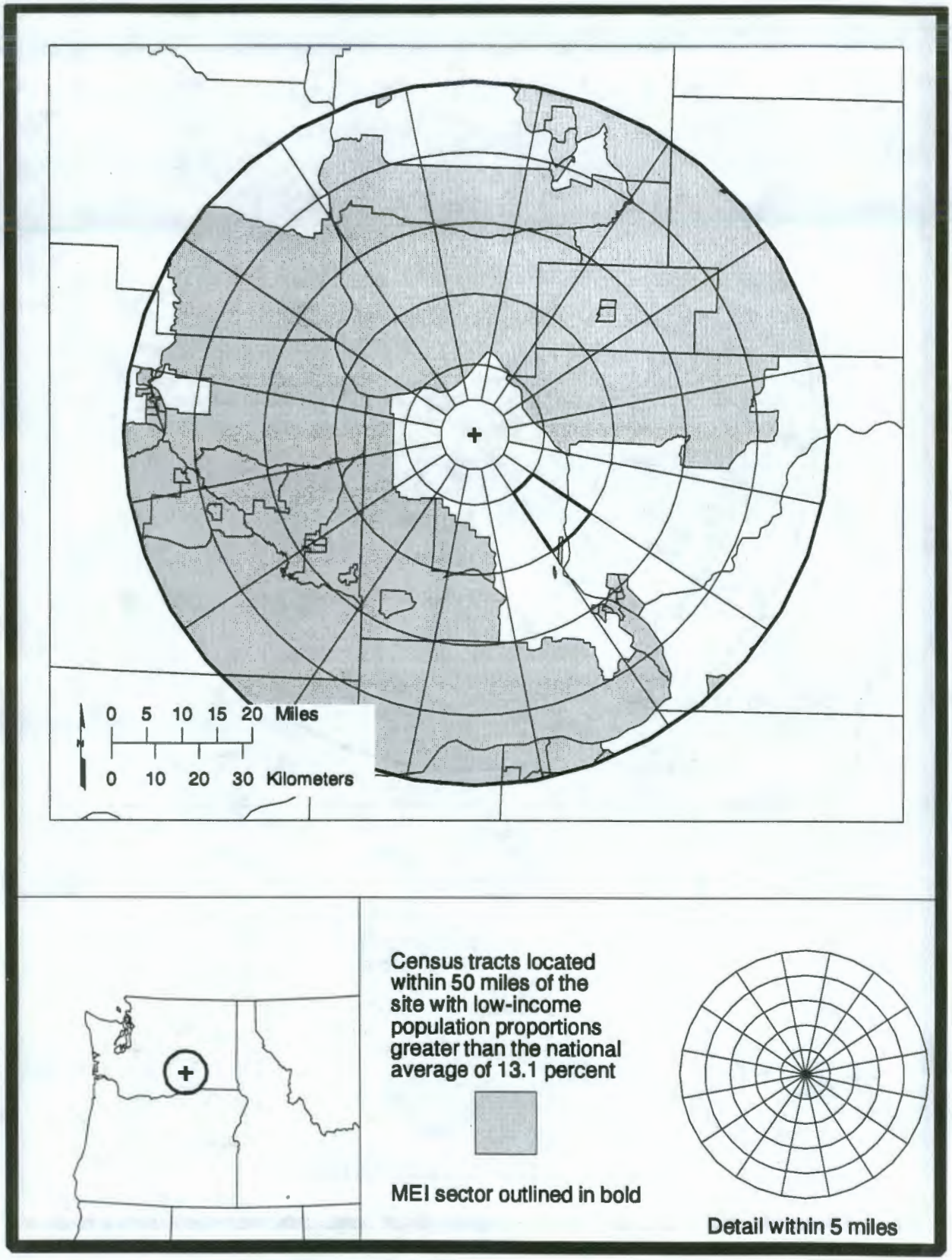


***Figure C.4–27. Distribution of Low-Income Populations at the Hanford Site.***

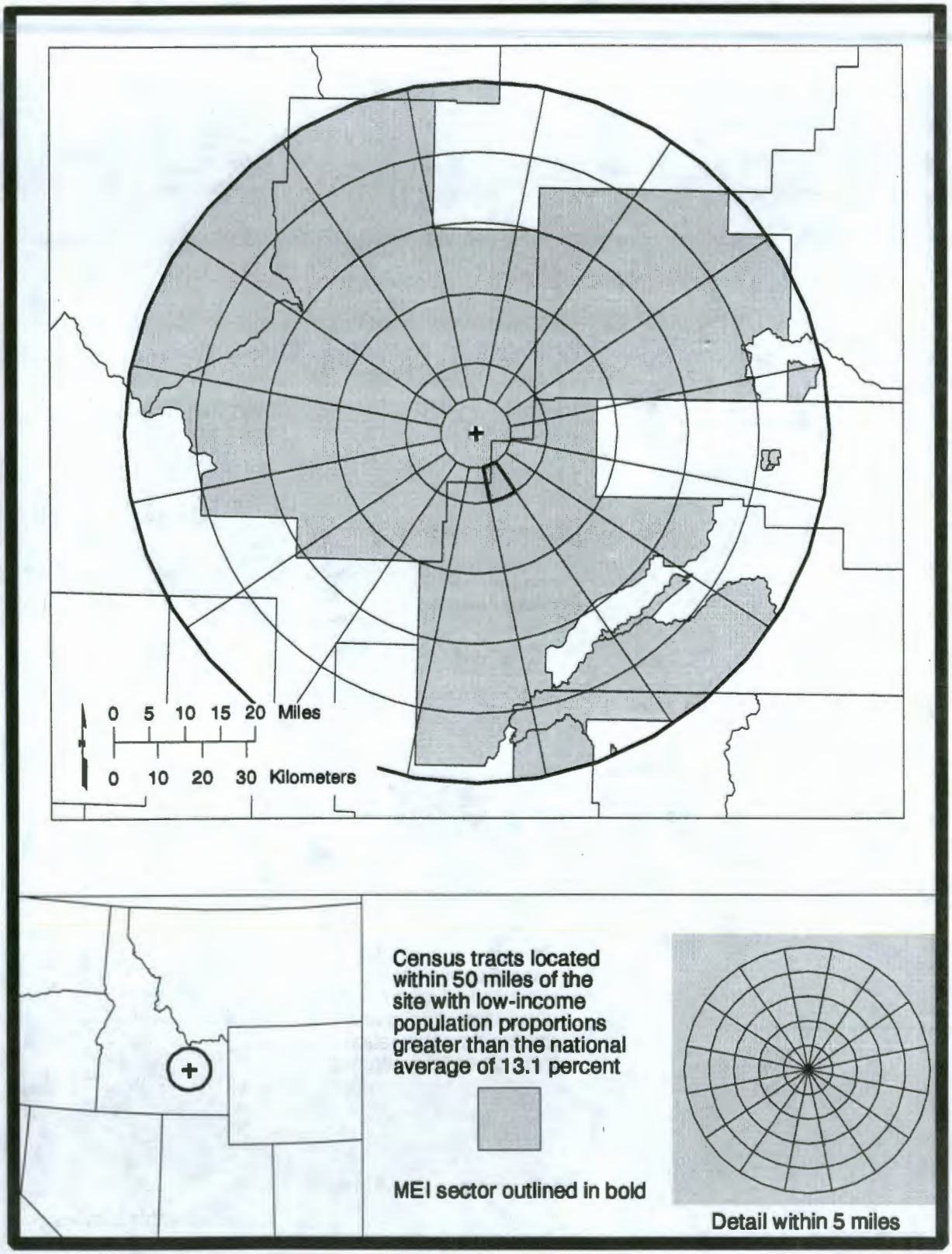


***Figure C.4–28. Distribution of Low-Income Populations at Idaho National Engineering Laboratory.***

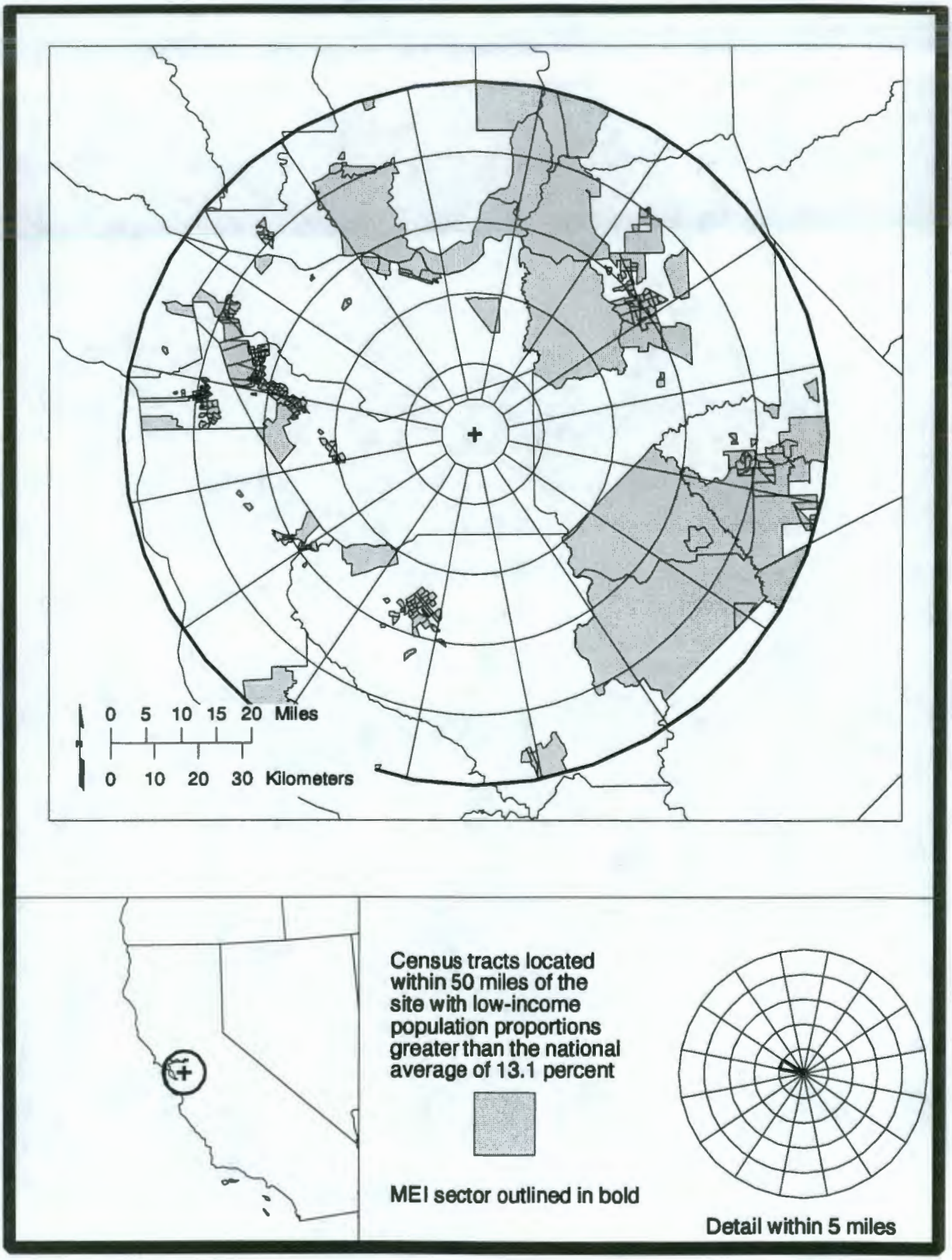


*Figure C.4–29. Distribution of Low-Income Populations at Lawrence Livermore National Laboratory.*

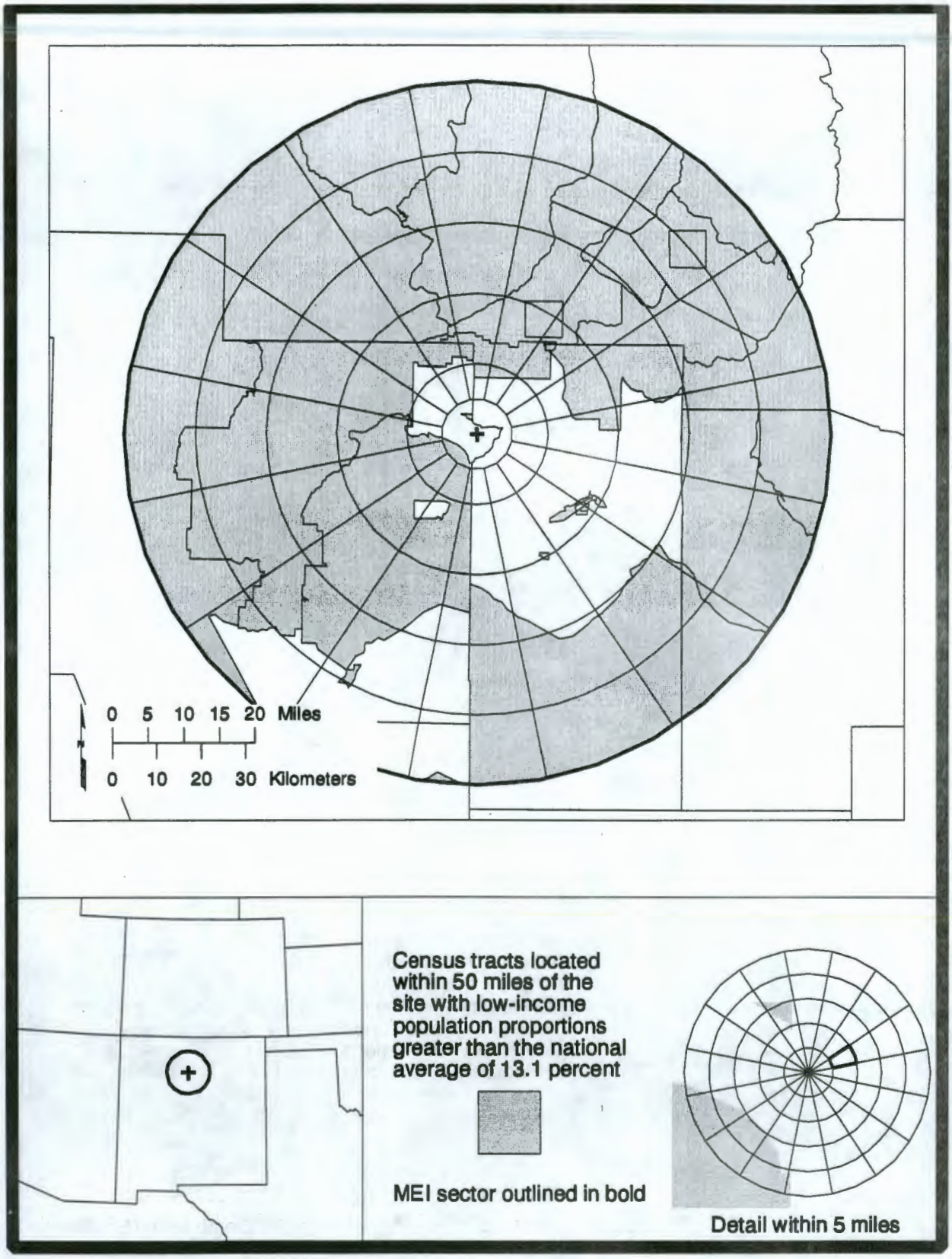


***Figure C.4–30. Distribution of Low-Income Populations at Los Alamos National Laboratory.***

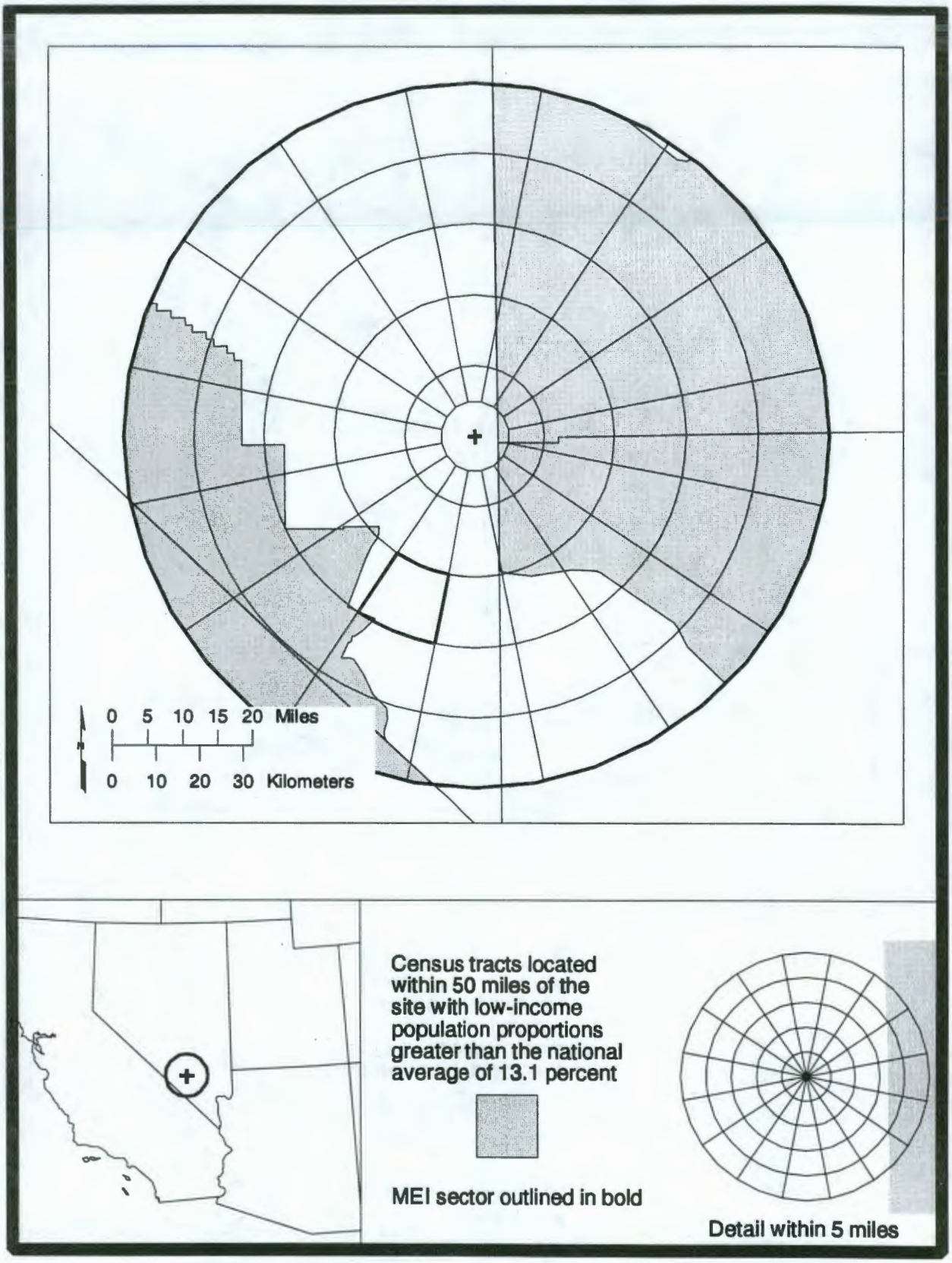


***Figure C.4–31. Distribution of Low-Income Populations at the Nevada Test Site.***

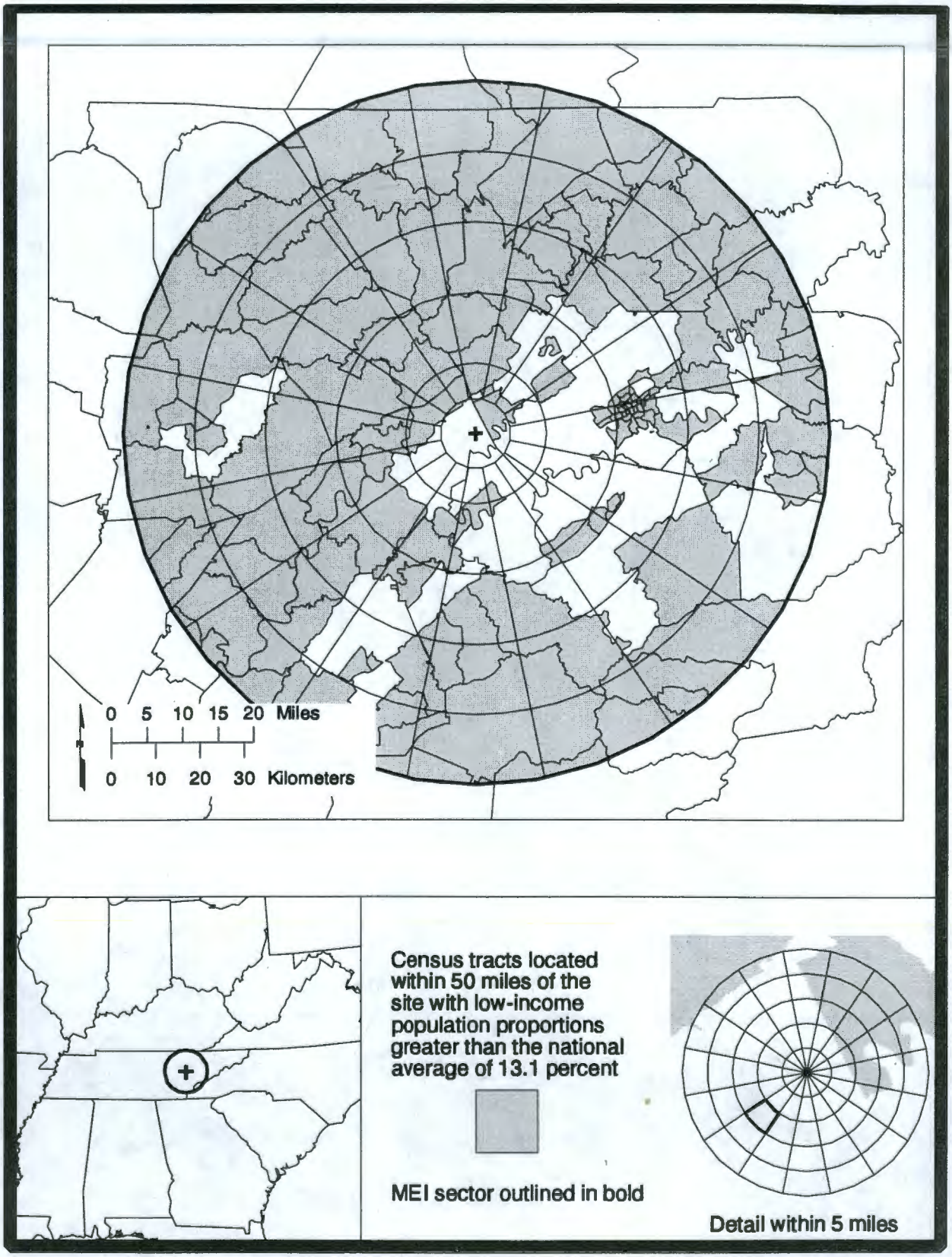


***Figure C.4–32. Distribution of Low-Income Populations at the Oak Ridge Reservation.***

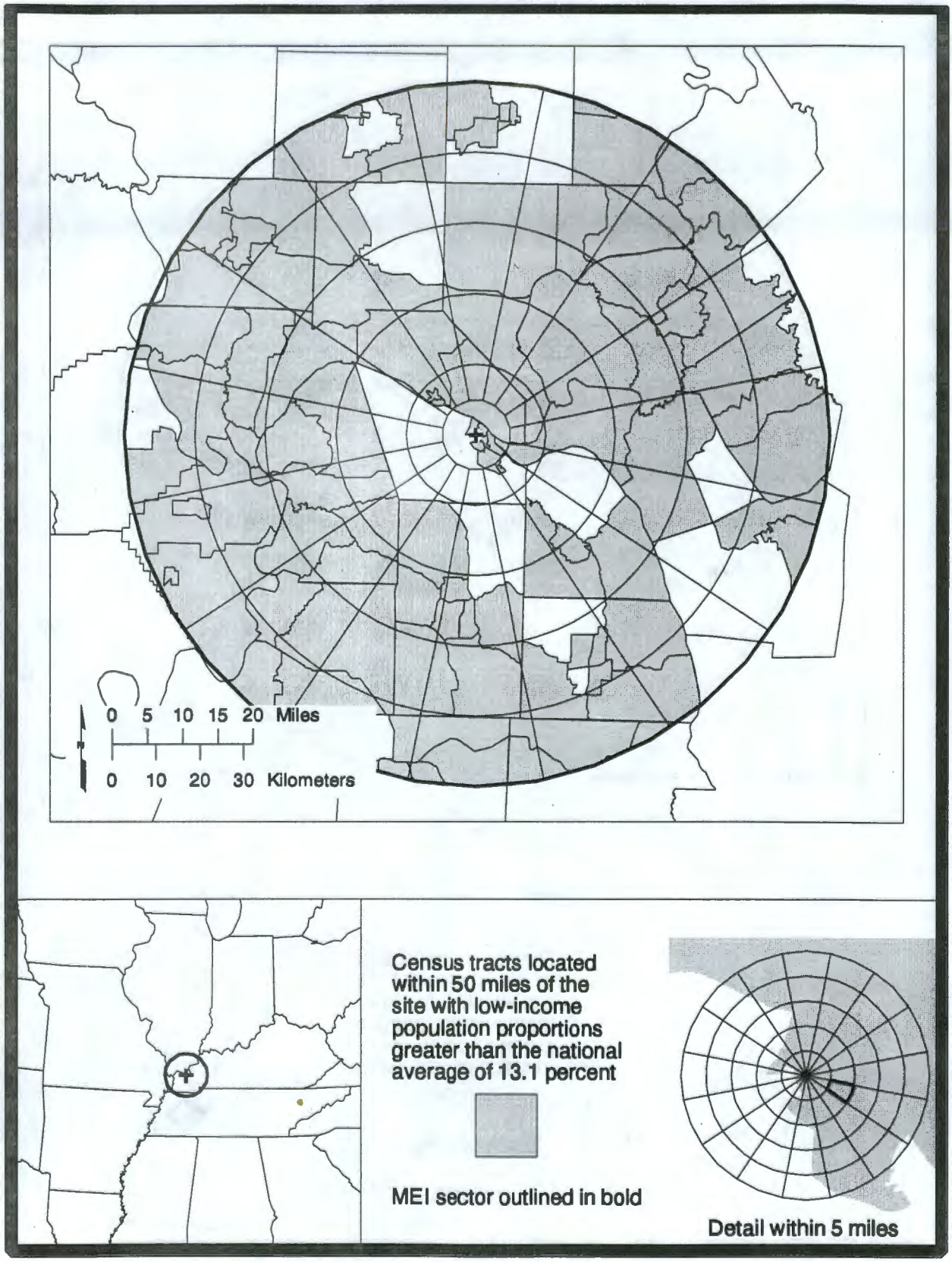


*Figure C.4–33. Distribution of Low-Income Populations at the Paducah Gaseous Diffusion Plant.*

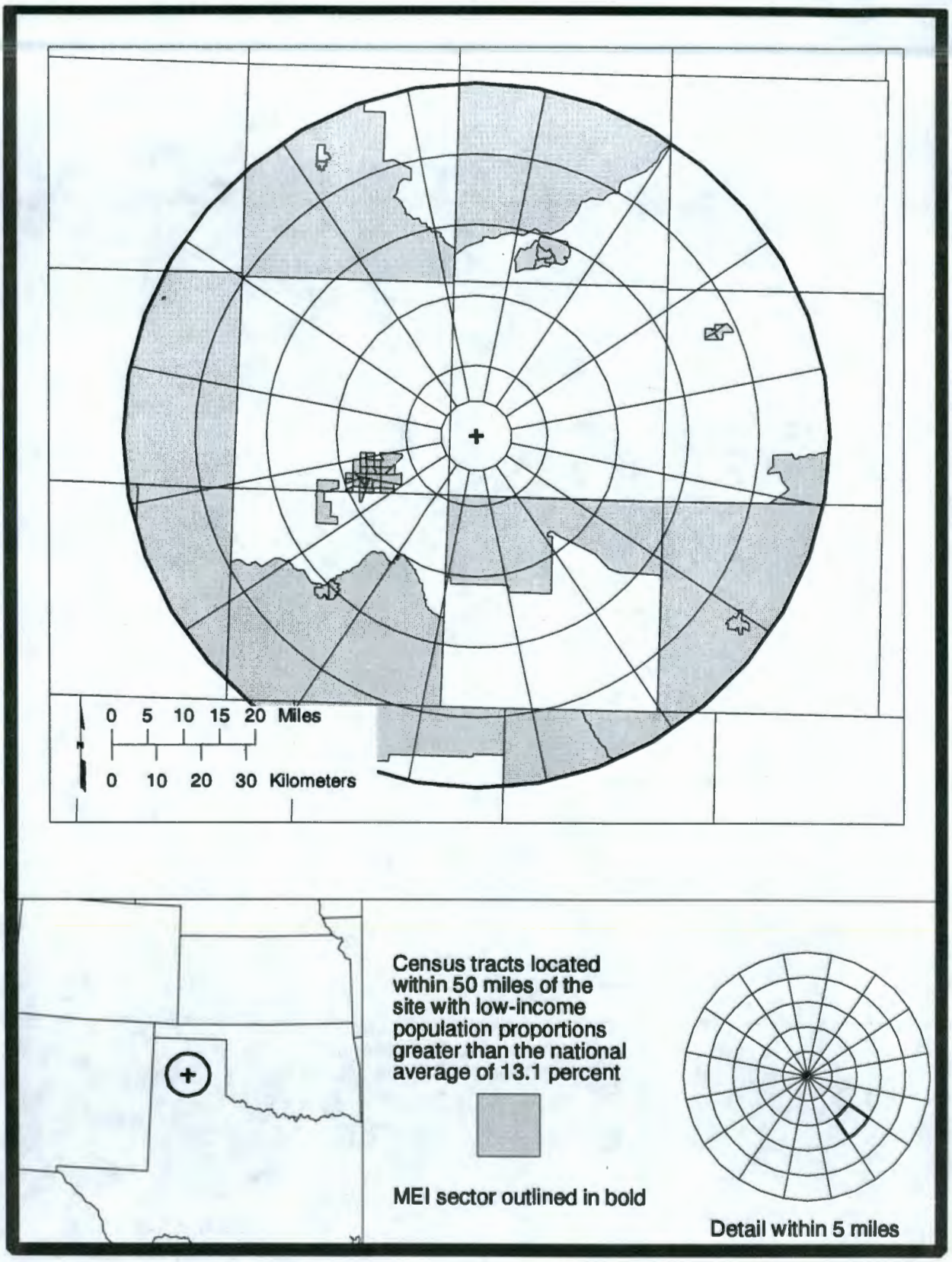


***Figure C.4–34. Distribution of Low-Income Populations at the Pantex Plant.***

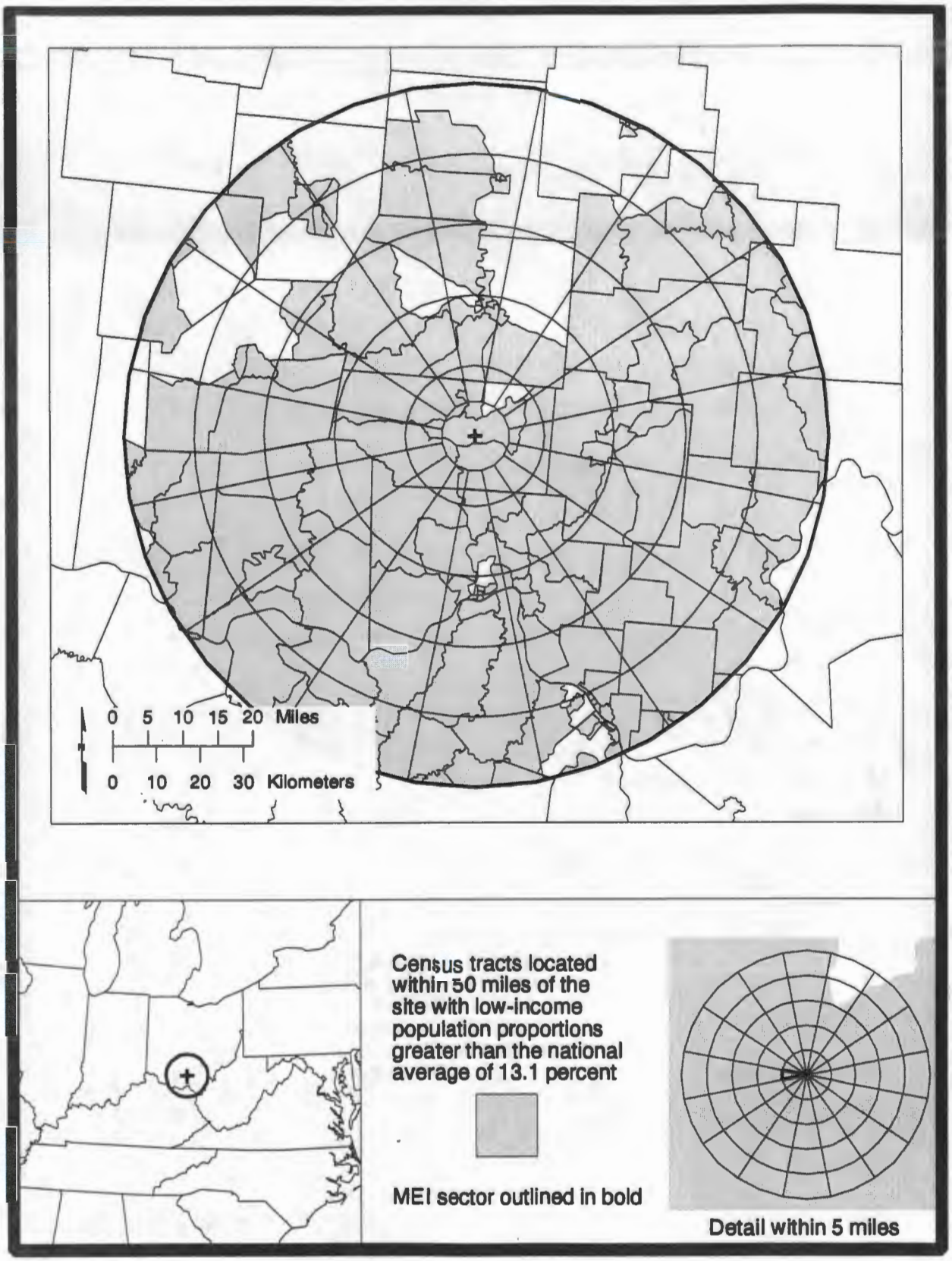


*Figure C.4–35. Distribution of Low-Income Populations at the Portsmouth Gaseous Diffusion Plant.*

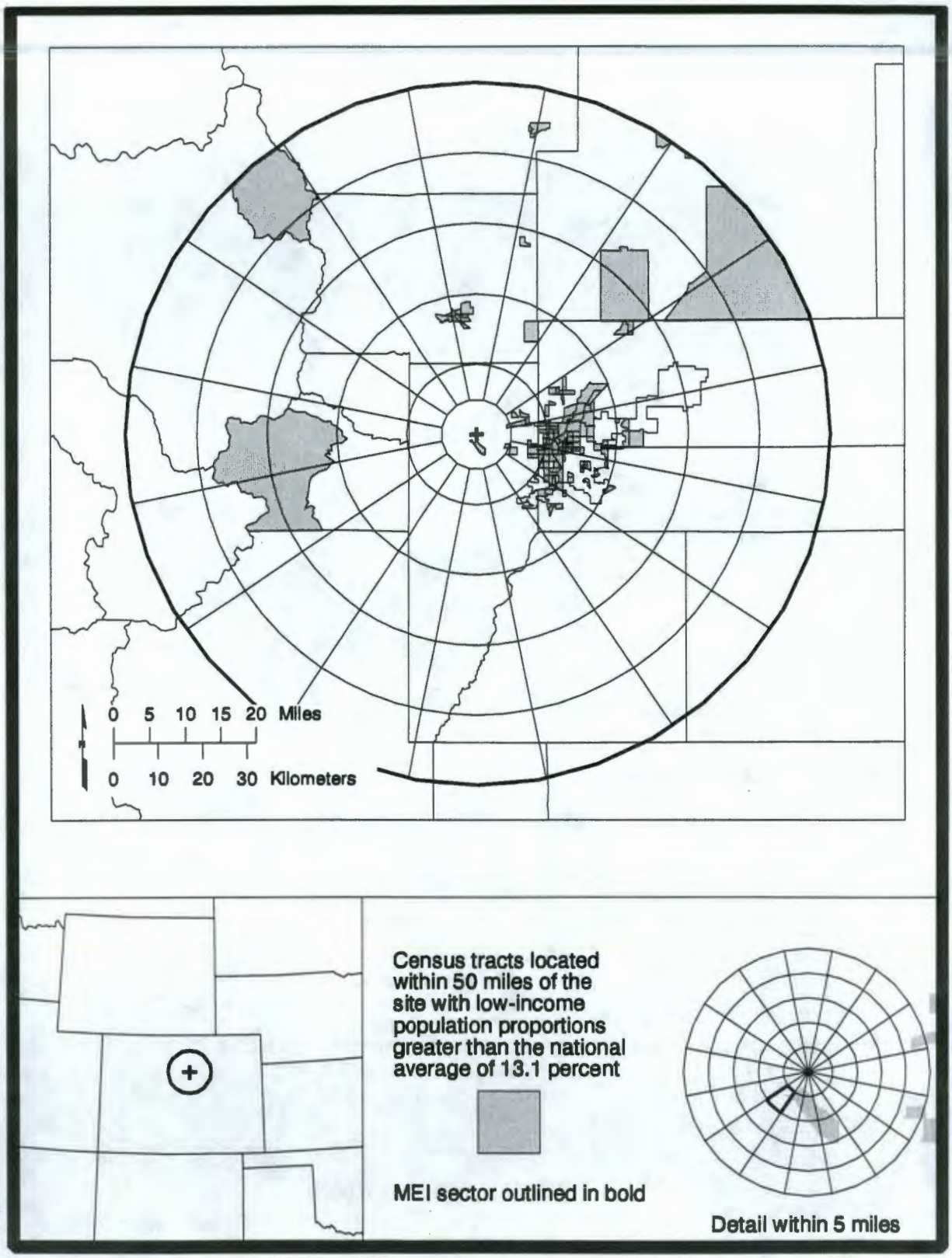


***Figure C.4–36. Distribution of Low-Income Populations at Rocky Flats Environmental Technology Site.***

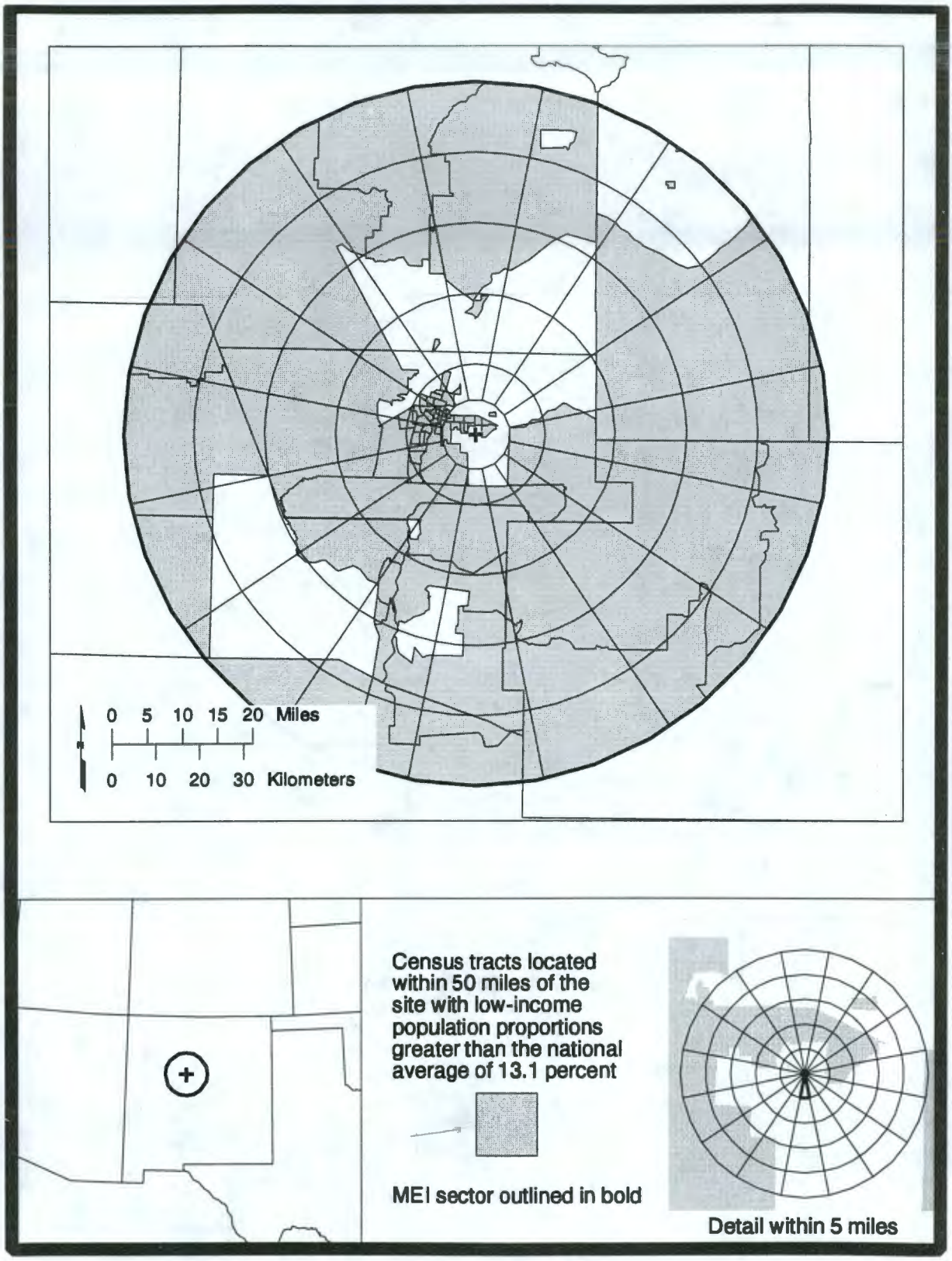


*Figure C.4–37. Distribution of Low-Income Populations at Sandia National Laboratories-New Mexico.*

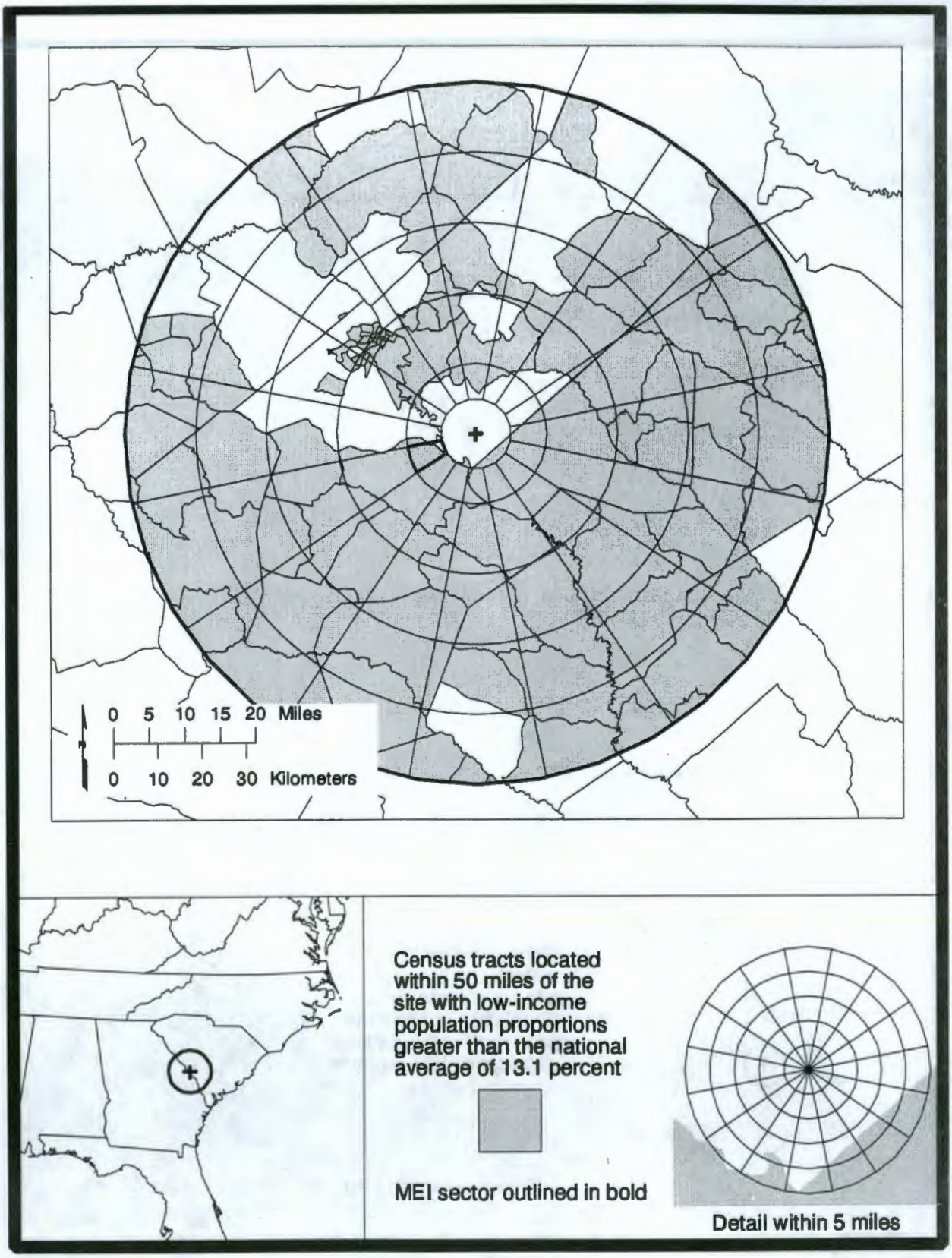


***Figure C.4–38. Distribution of Low-Income Populations at the Savannah River Site.***

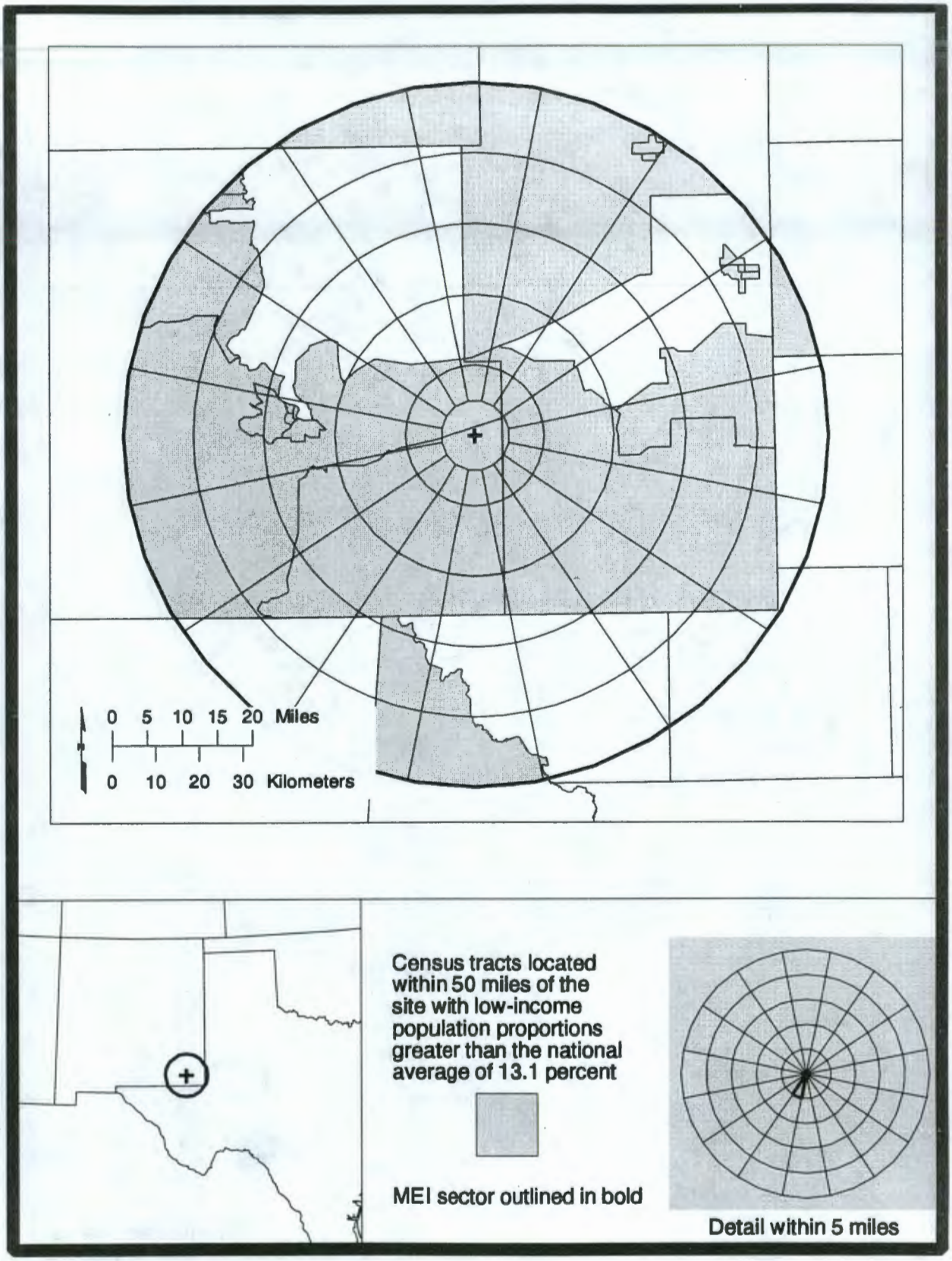


*Figure C.4–39. Distribution of Low-Income Populations at the Waste Isolation Pilot Plant.*

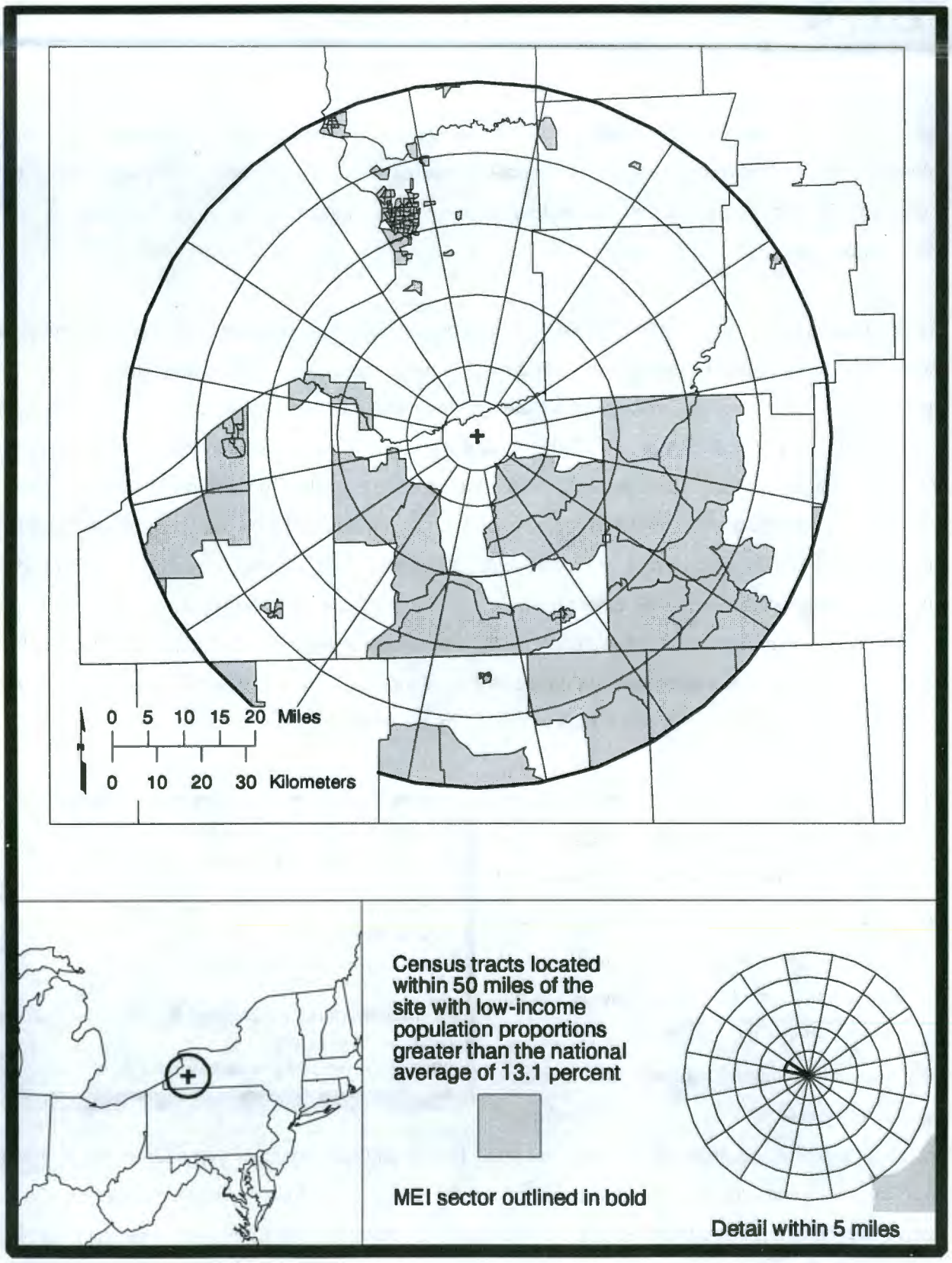


***Figure C.4–40. Distribution of Low-Income Populations at the West Valley Demonstration Plant.***

### C.4.7.2.4 *Vulnerability of Minority and Low-Income Population due to Subsistence Food Consumption*

Section 4-4 of Executive Order 12898 directs Federal agencies, "whenever practical and appropriate, to collect and analyze information on the consumption patterns of populations who principally rely on fish and/or wildlife for subsistence and that federal agencies communicate to the public the risks of these consumption patterns."

The potential environmental impacts of DOE activities on populations engaging in subsistence consumption could vary greatly depending on the precise location of a waste management facility at a particular site, the type of waste management facility, and the technology employed for the treatment or disposal of wastes at such a facility. In a prior NEPA review, DOE found the potential impacts associated with the consumption of fish and wildlife at INEL, Hanford, SRS, NTS, and ORR to be small or no different from the potential impacts on the general population (DOE, 1995c). DOE could not determine whether the impacts from fish consumption at WVDP were disproportionately high and adverse (DOE, 1996c). However, DOE predicted a high long-term risk of contracting cancer for a variety of groups (including Native Americans) for the No Action and long-term management alternatives for the Tank Waste Remediation System (TWRS) at Hanford (DOE, 1996d). The subsistence consumption scenario used for TWRS "has not received a complete review by the scientific community nor has it been approved by the potentially affected tribes" (DOE, 1996d).

To assemble and disseminate information on subsistence hunting and fishing, DOE began publishing *A Department of Energy Environmental Justice Newsletter: Subsistence and Environmental Health*, in the spring of 1996. The three goals of the newsletter are (1) "to provide useful information about the health implications of consuming contaminated fish, wildlife, livestock products or vegetation," (2) "to provide information about projects and programs at DOE and other federal and state agencies that address the problems associated with consuming contaminated fish, wildlife, livestock products, or vegetation," and (3) "to receive relevant information from readers." In addition to the newsletter, DOE has a new project underway

***Internet Access is Available for DOE's Environmental Justice Information***

*Subsistence and Environmental Health Newsletter On-line:*
*http://www.em.doe.gov/health/*

*Environmental Justice Strategy for the Department of Energy:*
*http://www.em.doe.gov/stake/envjus.html*

***Table C.4–25. Factors Contributing to the Possibility of Subsistence Consumption of Fish and Wildlife***

| Site | Federally Recognized Native American Groups[a] | Distance to Major Surface Water Bodies | Population in the 50-Mile Region of Influence (in millions) | Percentage Minority (within a 50-mile radius) | Percentage of Low Income Populations |
|---|---|---|---|---|---|
| **Sites with Higher Possibility of Subsistence Consumption** | | | | | |
| Hanford | Yes | On site | 0.35 | 25.8 | 18.8 |
| INEL | Yes | NA[b] | 0.11 | 10.2 | 12.5 |
| LANL | Yes | At site boundary | 0.27 | 48.1 | 13 |
| RFETS | Yes | On site | 1.98 | 19.7 | 9.8 |
| SNL | Yes | 6 miles | 0.61 | 45.1 | 14.8 |
| SRS | Yes | At site boundary | 0.59 | 37.8 | 18 |
| WIPP | Yes | NA | 0.10 | 36.9 | 21.6 |
| WVDP | Yes | On site | 1.54 | 11.6 | 12.2 |
| **Sites with Intermediate Possibility of Subsistence Consumption** | | | | | |
| NTS | Yes | NA | 0.01 | 12.8 | 12.6 |
| ORR | None | At site boundary | 0.88 | 6.1 | 16.2 |
| PGDP | None | <2 miles | 0.50 | 9.1 | 19.1 |
| PORTS | None | <1 mile | 0.61 | 3.2 | 20.8 |
| **Sites with Lower Possibility of Subsistence Consumption** | | | | | |
| ANL-E | None | <1 mile | 8.03 | 33.5 | 11.4 |
| BNL | None | On site | 5.26 | 21.4 | 5.4 |
| FEMP | None | <1 mile | 2.64 | 13.2 | 11.8 |
| LLNL | None | NA | 6.31 | 40.9 | 9.5 |
| Pantex | None | NA | 0.27 | 19.8 | 15.2 |

[a] The presence of a federally recognized Native American group was assumed to be the most important indicator of potential subsistence fishing and hunting. The remaining factors are listed in descending importance from left to right.
[b] NA = not applicable; no major surface water bodies within the region of influence.

to identify what information is being collected on subsistence consumption by other Federal agencies and to serve as a clearinghouse for such information.

In a recent article reviewing the literature on subsistence consumption, ANL found that (1) "the majority of the studies that have been conducted to date are focused on site- or region-specific exposure concerns. . . . At present, it is unclear whether the findings of these studies are representative of consumption and exposure levels among minority populations at a national level;" (2) "a large number of risk assessment studies focusing on fish and wildlife consumption examined whole populations without distinguishing between consumption and exposure patterns of specific ethnic (or other) subpopulations;" (3) "the vast majority of studies have focused on fish consumption as an exposure pathway. Few examined wildlife consumption and contamination, and even in such cases the studies were not motivated by minority exposure concerns;" and (4) "the majority of the studies identified found rates of fish and shellfish consumption among minority populations to be significantly higher than for the population as a whole" (Elliot, 1994).

With regard to the impacts analyzed in this PEIS, and in the absence of subsistence consumption data by population subgroups, DOE prepared Table C.4–25 using the following criteria and assumptions weighted in order of importance, to identify groups of sites that may be near minority and low income populations potentially engaging in subsistence consumption.

- Proximity of Tribal Lands to DOE sites (the presence of Native Americans near DOE sites is assumed to create a greater possibility for subsistence consumption)
- Distance of the DOE site to major surface water bodies (populations nearer water are assumed to have a greater possibility of subsistence consumption of fish)
- Population density in the 50-mile region of influence around the site (rural residents are assumed to have a greater possibility of engaging in subsistence hunting and fishing)
- Proximity and concentration of minority and low-income populations to DOE sites (higher concentrations of minority and low-income populations are assumed to have a greater potential for subsistence consumption)

The 17 major DOE sites appear in the table in three groups: those with the higher possibility for subsistence consumption, those with intermediate possibilities for subsistence consumption, and those with the lower possibilities for subsistence consumption. As Table C.4–25 shows, more rural sites with recognized Native American groups are assumed more likely to engage in subsistence hunting and fishing. These sites include

Hanford, INEL, LANL, RFETS, SNL, SRS, WIPP, and WVDP. Sites of intermediate concern include NTS, ORR, PGDP, and PORTS, because of the respective sites' rural surroundings, the presence of Native American populations, the presence of minority or low-income populations, or the presence of surface water on site. While sites like ANL-E and LLNL have a large percentage of minorities, both sites are in urban areas with populations of 8 and 6.3 million respectively. Because of these factors, ANL-E and LLNL are listed along with BNL, FEMP, and Pantex as having a lower possibility of populations who principally rely on fish and/or wildlife for subsistence.

### C.4.8 Land Use Impacts

The land use impacts analysis evaluated the potential for the management alternatives for the five waste types to adversely affect land use at the sites by comparing the amount of land required for proposed waste treatment, storage, or disposal facilities with the amount of land designated for future waste management operations in the site development plans for the 17 major sites. For those of the 17 sites not having a portion of the site designated for waste operations, the land required for waste management activities was compared with an estimated amount of land suitable for development. This estimate was made by subtracting from the total installation acreage the known or estimated acreage of land in existing structures, sensitive habitats including wetlands, topographic and surface water features, and other features such as wildlife management areas and cultural resources. At sites where the land requirement constitutes 1% or more of designated or suitable land, a potential for impacts is noted in the waste type impacts discussion and the percent required is listed in a summary table for the site/alternative. The text then discusses the severity of impacts depending on how great a portion of the available land is required and includes an indication of the likelihood of conflicts with land uses adjacent to the site. Where the land requirements for waste management activities exceeds the amount of land designated or suitable, the analysis indicates that significant land use impacts are likely. Apart from the analysis of the percent of suitable site land used, the analysis also indicates whether the description of future uses at the sites given in the site development plans appears to indicate a potential conflict between those planned uses and the uses proposed under the waste type alternatives.

### C.4.9 Infrastructure Impacts Methodology

Construction and operation of waste management facilities at the sites will increase the sites' use of water supply, wastewater treatment facilities, and electrical power systems and will increase traffic on site roads.

The impacts of the waste management alternatives on site water, wastewater, and power systems were evaluated using estimates of the percentage of existing system capacity the new requirements represented. Where the new requirements were substantial, they were added to current use rates and the sum compared to the existing supply capacities of those systems. Site transportation infrastructure impacts were assessed indirectly using increased site employment as an indicator of increased stress on the system. Impacts to community infrastructure systems were assessed using estimated waste management project-induced population increases as an indicator of increased demand on those systems. The impacts assessment evaluated the separate effects of the construction and operations phases for each alternative for each waste type.

### C.4.9.1 Site Infrastructure Impacts

The site infrastructure impacts analysis focused on the effects of the WM alternatives on the 17 major sites' water supply, wastewater treatment, and electrical power infrastructure systems. Data on new infrastructure requirements under each alternative are described in Section C.3.2 of this appendix. Current use rate and existing capacity data are described in PEIS Chapter 4 on the Affected Environment and in the Affected Environment Technical Report.

New project requirements of less than 5% of existing capacity were considered likely to have negligible or minor impacts on an infrastructure system and were not further evaluated. Moderate or major impacts were considered possible where increases in system requirements were 5% or greater. These cases were further evaluated on a site by site basis. Major impacts were considered possible where new requirements caused system capacity to be approached or exceeded. Therefore, any increase of 5% or greater that caused the total site use rate to exceed 90% of available capacity, was considered to have the potential to cause a major infrastructure impact. In such cases, site infrastructure may require substantial expansion or construction of new systems to meet the added demand. Such projects would have associated costs and environmental impacts beyond the direct impacts of the waste management facilities.

Where site infrastructure capacity information was not available, the new requirements were evaluated as a percentage of current use. In these cases, new requirements of less than 5% of current use were considered likely to have negligible or minor impacts. Increases in requirements from 5% to less than 15%

were considered to have the potential to cause moderate impacts, and increases of 15% or greater were considered to have the potential to cause major impacts.

Site transportation infrastructure impacts were evaluated indirectly by comparing new site employment to existing site employment as an indicator of increased stress on site transportation systems. New site employment of less than 5% of current employment was considered likely to have negligible or minor impacts. Site employment increases from 5% to less than 15% were considered to have the potential to cause moderate impacts, and increases of 15% or greater were considered to have the potential to cause major impacts.

### C.4.9.2 Community Infrastructure Impacts

Community infrastructure would be affected indirectly by any substantial increase in population caused by the influx of labor to implement the WM alternatives. Community infrastructure impacts were evaluated by comparing estimated population increases with current population levels as an indicator of increased use rates of community infrastructure systems. This analysis was based on the in-migration estimates and 1990 regional population data described in the social impacts analysis (see Section C.4.6). Population increases of less than 5% of current (1990 census) population levels were considered to have the potential to cause negligible or minor impacts. Increases of 5% or greater were considered to have the potential to cause moderate impacts, and increases of 15% or greater were considered to have the potential for major infrastructure impacts.

### C.4.9.3 Site and Community Infrastructure Baseline

Baseline water, wastewater, and power information can be found in the Affected Environment chapter and appendix. The information is summarized below. Proposed resource requirements under the alternatives are compared to the current capacity to determine whether increased use will impact the infrastructure systems. Site employment information is provided in the socioeconomic impacts discussion and is summarized in Table C.4–26. Proposed increases in site employment under the various alternatives is compared to current site employment to determine possible impacts to transportation infrastructure.

*Table C.4–26. Baseline Infrastructure Data for the 17 Major DOE Sites*

| Site | Water (gpd) | | Wastewater (gpd) | | Power (MW) | | Site Employment |
|---|---|---|---|---|---|---|---|
| | Current Use | Capacity | Current Use | Capacity | Current Use | Capacity | |
| ANL-E | 625,000 | 1,800,000 | 434,000 | 2,600,000 | 23 | NA | 4,455 |
| BNL | 3,500,000 | 6,000,000 | 1,000,000 | 2,300,000 | 35 | 47 | 3,557 |
| FEMP | 400,000 | 1,600,000 | 2,180,000 | 2,270,000 | 33 | NA | 1,939 |
| Hanford | 9,510,000 | 79,060,000 | 158,000 | 200,000 | 550 | NA | 14,394 |
| INEL | 5,242,000 | 30,630,000 | 254,000 | unlimited | 42 | NA | 11,813 |
| LANL | 4,100,000 | 10,000,000 | NA | 1,000,000 | 68 | 120 | 6,199 |
| LLNL | 717,000 | 2,520,000 | 400,000 | 1,680,000 | 61 | 100 | 8,173 |
| NTS | 1,360,000 | 2,780,000 | 140,000 | 338,000 | 30 | 45 | 7,086 |
| ORR | 18,300,000 | 40,200,000 | 2,000,000 | 4,100,000 | 116 | 660 | 21,544 |
| PGDP | 15,000,000 | 30,000,000 | 400,000 | 1,750,000 | 1,564 | 3,040 | 1,740 |
| Pantex | 500,000 | 1,500,000 | 275,000 | 545,000 | 13 | 1,523 | 2,891 |
| PORTS | 14,000,000 | 37,000,000 | 350,000 | 1,200,000 | 1,537 | 1,929 | 2,386 |
| RFETS | 272,000 | 1,000,000 | 150,000 | 500,000 | 18 | 35 | 7,365 |
| SNL | 1,000,000 | 4,030,000 | 548,000 | NA | 35 | 50 | 8,596 |
| SRS | 1,600,000 | 5,000,000 | 500,000 | 750,000 | 80 | 175 | 17,319 |
| WIPP | 14,000 | 540,000 | 12,000 | 185,000 | NA | NA | 932 |
| WVDP | 70,000 | 110,000 | 70,000 | 70,000 | 3 | 7 | 1,100 |

Notes: gpd = gallons per day; NA = not available. Data for baseline infrastructure represent onsite use only. Wastewater use and capacity are based on sanitary waste. No process wastes are included.

## C.4.10 Cultural Resources Impacts

The potential for cultural resources to be affected by waste management activities was considered by using the estimated acreage of site disturbance to construct waste management facilities under each waste-type alternative as an estimate of the area of potential cultural resource effects and as a comparative indicator of the extent of the cultural resource survey requirements at each site. Cultural resources impacts were not directly evaluated in the PEIS because the analysis would require identification of specific locations of proposed waste management facilities.

### C.4.10.1 Cultural Resources Considered

The cultural resources considered in this analysis include prehistoric and historic resources, and Native American resources. Paleontological resources, though not cultural in origin, are also included because of their recognized value and similar need for protection.

#### C.4.10.1.1 *Prehistoric and Historic Properties*

A "historic property" is an archeological site, standing structure, or traditional cultural property that is listed or is potentially eligible for listing on the National Register of Historic Places (36 CFR 60). Requirements for the assessment of historic properties for the PEIS are met through compliance with Section 106 of the National Historic Preservation Act of 1966 (16 USC 470), as amended, with implementing regulations contained in 36 CFR 800. In general, Federal agencies are required to determine the effects of proposed actions on significant historic properties within a defined area of potential effects.

#### C.4.10.1.2 *Native American Resources*

Resources that may be of concern to Native Americans may be structures, regional locations, natural features, native plants, objects and other materials that are considered to be of value to contemporary Native American groups for traditional, religious, or ceremonial purposes. Examples of these resources can include burial grounds, sacred sites, and areas, materials for the production of sacred objects and traditional implements, and botanical, biological, and geological resources of ritual importance. Impacts to these areas include both direct physical impacts (destruction, loss of access) and indirect social and economic effects. Several laws and Executive Orders are specifically applicable to the protection of Native American resources including American Indian Religious Freedom Act of 1978 (42 USC 1996), the Native American Graves Protection and Repatriation Act of 1990 (25 USC 3001 *et seq.*), and Executive Order 13007 regarding sacred sites. Determination of potential impact to these sites is similar to that for other historic properties.

### C.4.10.1.3 *Paleontological Resources*

Paleontological materials and features are the physical remains of life forms (fossils) from a former geologic age. These include the remains of animals, plants, or trace fossils such as impressions, burrows or tracks. Although paleontological resources are not treated with the same level of specificity as archeological or historic properties, they are included in several Federal statutes such as the Archeological Resources Protection Act of 1979 (16 USC 470aa-470ll) and the Federal Land Management Policy Act of 1976 (43 USC 1701 *et seq.*).

## C.4.10.2 Cultural Resources Protection Procedures

Federal agencies protect cultural resources through compliance with Section 106 of the National Historic Preservation Act of 1966, as amended, which is implemented through regulations contained in 36 CFR 800. These regulations require Federal agencies to consider the existing information, undertake identification activities if the existing information is insufficient, determine whether any cultural resources contained within the agency-defined area of potential effects meet the criteria for eligibility for inclusion in the National Register of Historic Places, determine the effect of the proposed action on significant historic properties, consult with the State Historic Preservation Office (SHPO), and afford the Advisory Council on Historic Preservation (ACHP) the opportunity to comment.

To comply with 36 CFR 800, the lead federal agency defines an "area of potential effects," or project area, for the proposed action. The project area usually comprises the physical limits of disturbance or alteration that will result from the proposed actions, such as construction, demolition, staging, or operation of a facility.

The next step in the process is to identify the presence of absence of historic properties within the area of potential effects (36 CFR 800.4). An "historic property" is an archeological site, standing structure, or traditional cultural property that is listed or is potentially eligible for listing on the National Register of Historic Places (NRHP) (36 CFR 60). Identificational studies can comprise a variety of site-specific archaeological, architectural, or cultural surveys of the undertaking's project area. Other studies may be conducted in order to evaluate an identified resource's eligibility for inclusion on NRHP.

If no cultural resources eligible or potentially eligible for the NRHP are identified during these studies, then, given the concurrence of the SHPO, the project will have no effect on historic properties and the undertaking may proceed. If historic properties are identified within the project area, then the agency in consultation with the SHPO must apply the "criteria or effect and adverse effect" as defined in 36 CFR 800.5 and 800.9.

An undertaking is considered to have an adverse effect when the effect on a historic property may diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. Adverse effects on historic properties include, but are not limited to:

- Physical destruction, damage, or alteration to all or part of the property
- Isolation of the property from or alteration to the character of the property's setting when that character contributes to the property's qualification for the National Register
- Introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting
- Neglect of a property resulting in its deterioration or destruction
- Transfer, lease, or sale of the property (36 CFR 800.9.b.1-5)

### C.4.10.3 Consideration of Cultural Resources Impacts in the WM PEIS

Given the various levels of cultural resource information (the number of recorded resources and the size of surveyed areas) associated with DOE facilities across the country and the cultural resource diversity known or presumed to be located at these sites, the specific analysis of impacts must be left to site-specific or project-level NEPA documents. In addition, the locations of the different waste management activities at individual sites have not been identified. Thus, at the programmatic level, both the specific area of potential effects and the presence or absence of National Register eligible historic properties are at present unknown. Therefore, evaluation of potential impacts in this PEIS was limited to providing relevant information on existing cultural resources identified at the sites (see Chapter 4, Affected Environment) and an estimate of the extent to which potential new site surveys would be required (see the Cultural Impacts sections in the waste-type Chapters 6–10).

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# Appendix D

# Waste Management Facility Human Health Risk Estimates

U.S. Department of Energy
Waste Management Programmatic Environmental Impact Statement

# Contents


Acronyms and Abbreviations . . . . . D-xxvii

D.1 Introduction . . . . . D–1

D.1.1 Purpose of the Waste Management Human Health Risk Evaluation . . . . . D–2

D.1.2 Waste Types Evaluated . . . . . D–2

D.1.3 Waste Consolidation Alternatives . . . . . D–3

D.2 Evaluating the Risks Associated With Waste Management Activities . . . . . D–4

D.2.1 Characterizing the Environmental Setting . . . . . D–5

D.2.2 Identifying Potentially Exposed Populations . . . . . D–5

D.2.2.1 Populations Not Specifically Evaluated . . . . . D–7

D.2.3 Identifying Environmental Transport Pathways . . . . . D–9

D.2.3.1 Transport Pathways Not Evaluated . . . . . D–10

D.2.4 Identifying Likely Exposure Routes for Populations and Individuals . . . . . D–12

D.2.4.1 Offsite and Noninvolved Worker Population Exposure Routes . . . . . D–12

D.2.4.2 Hypothetical Farm Family Exposure Routes . . . . . D–12

D.2.4.3 Hypothetical Intruder Exposure Routes . . . . . D–17

D.2.4.4 Worker Exposure Routes . . . . . D–17

D.2.5 Identifying the Human Health Effects to Be Evaluated . . . . . D–17

D.2.5.1 Factors Excluded From the Analysis . . . . . D–19

D.2.6 Quantifying Contaminant Intakes, Doses, and Exposures . . . . . D–19

D.2.6.1 Quantifying Chemical Intake and Exposure . . . . . D–20

D.2.6.2 Quantifying Radiological Dose and Exposure . . . . . D–20

D.2.6.3 Comparing Radionuclide Exposures to Chemical Exposures . . . . . D–22

D.2.7 Calculating Exposures for the PEIS Receptors . . . . . D–24

D.2.7.1 Calculating Exposures to the Offsite and Noninvolved Populations, Hypothetical Farm Family, and Hypothetical Intruder . . . . . D–24

D.2.7.2 Calculating Exposures to Waste Management Workers . . . . . D–27

D.2.8 Calculating Risks . . . . . D–29

D.2.8.1 Scaling Unit Doses and Intakes According to Installation Source Term . . . . . D–30

D.2.8.2 Calculating Risks From Unit Doses and Intakes . . . . . D–30

D.2.9 Calculating and Interpreting the Hazard Index . . . . . D–34

D.2.10 Calculating and Interpreting the Exposure Index . . . . . D–35

D.2.11 Calculating and Interpreting the IDLH Index for Accidents . . . . . D–35

D.2.12 Assessing the Risks From Potential Accidents . . . . . D–36

D.2.12.1 Predicted Annual Frequency of Accidents . . . . . D–37

D.2.13 Contents of the Risk Analysis Tables . . . . . D–38

D.2.14 Reading and Interpreting the Risk and Probability Numbers . . . . . D–38

D.2.15 Overview of Uncertainties in the PEIS Risk Analysis Process . . . . . D–40

D.3 Risk Analysis by Waste Stream . . . . . D–42

| | | |
|---|---|---|
| D.3.1 | High-Level Waste | D–42 |
| D.3.1.1 | Summary of HLW Alternatives | D–43 |
| D.3.1.2 | Special Assumptions and Considerations Used in the HLW Risk Analysis | D–44 |
| D.3.1.3 | Results Tables for the HLW Human Health Risk Analysis | D–45 |
| D.3.1.4 | Results of the HLW Human Health Risk Analysis for Routine Operations | D–51 |
| D.3.1.5 | Special Assumptions and Considerations Used in the HLW Accident Analysis | D–52 |
| D.3.1.6 | Results Tables for the Risk Analysis of Potential HLW Accidents | D–53 |
| D.3.1.7 | Summary of the HLW Accident Analysis Results | D–55 |
| D.3.2 | Low-Level Waste | D–55 |
| D.3.2.1 | Summary of LLW Alternatives | D–59 |
| D.3.2.2 | Special Assumptions and Considerations Used in the LLW Risk Analysis | D–59 |
| D.3.2.3 | Results Tables for the LLW Human Health Risk Analysis | D–60 |
| D.3.2.4 | Results of the LLW Human Health Risk Analysis for Routine Operations | D–110 |
| D.3.2.4.1 | Programwide Trends in Human Health Risks Associated With LLW Management Alternatives | D–110 |
| D.3.2.4.2 | Programwide Trends in Human Health Risks Associated With LLW Disposal | D–113 |
| D.3.2.4.3 | Comparison Among Treatment Options | D–115 |
| D.3.2.4.4 | Comparison Among Disposal Scenarios | D–116 |
| D.3.2.4.5 | Summary of Results for Routine Treatment and Disposal of LLW | D–116 |
| D.3.2.5 | Summary of Alternatives for Potential LLW Accidents | D–117 |
| D.3.2.6 | Special Assumptions and Considerations Used in the LLW Accident Analysis | D–118 |
| D.3.2.7 | Results Tables for the Risk Analysis of Potential LLW Accidents | D–118 |
| D.3.2.8 | Summary of the LLW Accident Analysis Results | D–127 |
| D.3.2.8.1 | Risks to the Offsite Population From LLW Accidents | D–127 |
| D.3.2.8.2 | Risks to the Noninvolved Worker Population From LLW Accidents | D–128 |
| D.3.2.8.3 | Risks to the Maximally Exposed Noninvolved Worker and Maximally Exposed Offsite Individual From LLW Accidents | D–128 |
| D.3.2.8.4 | Risks to Waste Management Workers From LLW Accidents | D–129 |
| D.3.2.9 | Risks to the Hypothetical Intruder From LLW Disposal | D–130 |
| D.3.2.9.1 | Results of the Human Health Risk Analysis for the Intruder | D–133 |
| D.3.3 | Hazardous Waste | D–134 |
| D.3.3.1 | Summary of HW Alternatives | D–135 |
| D.3.3.2 | Special Assumptions and Considerations Used in the HW Risk Analysis | D–136 |

D.3.3.3 Results Tables for the HW Human Health Risk Analysis . . . . . D–139
D.3.3.4 Results of the HW Human Health Risk Analysis for Routine Operations . . . . . D–146
D.3.3.4.1 Programwide Trends in Human Health Risks Associated With HW Management Alternatives . . . . . D–146
D.3.3.4.2 Summary of Results for Routine Treatment of HW . . . . . D–148
D.3.3.4.3 Discussion . . . . . D–148
D.3.3.5 Summary of Alternatives for Potential HW Accidents . . . . . D–149
D.3.3.5.1 Single-Drum Accidents . . . . . D–149
D.3.3.5.2 Storage Facility Accidents . . . . . D–150
D.3.3.5.3 Treatment Facility Accidents . . . . . D–152
D.3.3.6 Special Assumptions and Considerations Used in the HW Accident Analysis . . . . . D–152
D.3.3.7 Results Tables for the Risk Analysis of Potential HW Accidents . . . . . D–154
D.3.3.8 Summary of the HW Accident Analysis Results . . . . . D–160
D.3.3.8.1 Risks to the Offsite Population From Accidents During Storage . . . . . D–160
D.3.3.8.2 Risks to the Offsite Population From Accidents During Treatment . . . . . D–161
D.3.3.8.3 Risks to the Noninvolved Worker Population From Accidents During Storage . . . . . D–162
D.3.3.8.4 Risks to the Noninvolved Worker Population From Accidents During Treatment . . . . . D–162
D.3.3.8.5 Risks to the Maximally Exposed Offsite Individual From Single-Drum Accidents . . . . . D–163
D.3.3.8.6 Risks to the Maximally Exposed Noninvolved Worker and Maximally Exposed Offsite Individual From Storage Facility Accidents . . . . . D–163
D.3.3.8.7 Risks to Waste Management Workers From Storage and Treatment Facility Accidents . . . . . D–164
D.3.4 Transuranic Waste . . . . . D–165
D.3.4.1 Summary of CH-TRUW Alternatives . . . . . D–169
D.3.4.2 Special Assumptions and Considerations Used in the TRUW Risk Analysis . . . . . D–172
D.3.4.3 Results Tables for the CH-TRUW Human Health Risk Analysis . . . . . D–173
D.3.4.4 Results of the CH-TRUW Human Health Risk Analysis for Routine Operations . . . . . D–188
D.3.4.4.1 Programwide Trends in Human Health Risks Associated With CH-TRUW Management Alternatives . . . . . D–188
D.3.4.4.2 Comparison of the Decentralized Alternative and Regionalized Alternative 1: Treatment to WIPP Waste Acceptance Criteria Versus Treatment to Reduce Gas Generation . . . . . D–194
D.3.4.4.3 Comparison of Regionalized Alternatives 1 and 2: Treatment to Reduce Gas Generation Versus Treatment to Meet Land Disposal Restrictions . . . . . D–194

D.3.4.4.4 Comparison of the Regionalized 2, 3, and Centralized Alternatives: Differences in Consolidation Configuration . . . . . D–195
D.3.4.4.5 Summary of the Human Health Risk Analysis for Routine Management of CH-TRUW . . . . . D–196
D.3.4.5 Summary of RH-TRUW Alternatives . . . . . D–196
D.3.4.6 Results Tables for the RH-TRUW Human Health Risk Analysis . . . . . D–199
D.3.4.7 Results of the RH-TRUW Human Health Risk Analysis . . . . . D–208
D.3.4.7.1 Programwide Trends in Human Health Risks Associated With RH-TRUW Management Alternatives . . . . . D–208
D.3.4.7.2 Comparison of the Decentralized and Regionalized 1 Alternatives: Treatment to WIPP Waste Acceptance Criteria Versus Treatment to Reduce Gas Generation . . . . . D–211
D.3.4.7.3 Comparison of Regionalized Alternative 1 With Regionalized Alternatives 2 and 3 and the Centralized Alternative: Treatment to Reduce Gas Generation Versus Treatment to Meet Land Disposal Restrictions . . . . . D–211
D.3.4.7.4 Summary . . . . . D–212
D.3.4.8 Summary of Alternatives for Potential CH-TRUW Accidents . . . . . D–212
D.3.4.9 Special Assumptions and Considerations Used in the CH-TRUW Accident Analysis . . . . . D-213
D.3.4.10 Results Tables for the Risk Analysis of Potential CH-TRUW Accidents . . . . . D-213
D.3.4.11 Summary of the CH-TRUW Accident Analysis Results . . . . . D-220
D.3.4.11.1 Risks to the Offsite Population From CH-TRUW Accidents . . . . . D-220
D.3.4.11.2 Risks to the Noninvolved Worker Population From CH-TRUW Accidents . . . . . D-221
D.3.4.11.3 Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual From CH-TRUW Accidents . . . . . D-222
D.3.4.11.4 Risks to Waste Management Workers From CH-TRUW Accidents . . . . . D-223
D.3.4.12 Summary of Alternatives for Potential RH-TRUW Accidents . . . . . D-224
D.3.4.13 Results Tables for the Risk Analysis of Potential RH-TRUW Accidents . . . . . D-224
D.3.4.14 Summary of the RH-TRUW Accident Analysis Results . . . . . D-226
D.3.4.14.1 Risks to the Offsite Population From RH-TRUW Accidents . . . . . D-226
D.3.4.14.2 Risks to the Noninvolved Work Population From RH-TRUW Accidents . . . . . D-227
D.3.4.14.3 Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual From RH-TRUW Accidents . . . . . D-228
D.3.4.14.4 Risks to Waste Management Workers From RH-TRUW Accidents . . . . . D-229
D.3.5 Low-Level Mixed Waste . . . . . D–230

D.3.5.1 Summary of LLMW Alternatives . . . . . D-232
D.3.5.2 Special Assumptions and Considerations Used in the LLMW Risk Analysis . . . . . D-232
D.3.5.3 Results Tables for the LLMW Human Health Risk Analysis . . . . . D-234
D.3.5.4 Results of the LLMW Human Health Risk Analysis for Routine Operations . . . . . D-262
D.3.5.4.1 Programwide Trends in Human Health Risks Associated With LLMW Management Alternatives . . . . . D-262
D.3.5.4.2 Programwide Trends in Human Health Risks Associated With LLMW Disposal . . . . . D-263
D.3.5.4.3 Comparison Among Treatment Options . . . . . D-270
D.3.5.4.4 Comparison Among Disposal Scenarios . . . . . D-270
D.3.5.4.5 Summary of Results for Routine Treatment and Disposal of LLMW . . . . . D-271
D.3.5.5 Summary of Alternatives for Potential LLMW Accidents . . . . . D-271
D.3.5.6 Special Assumptions and Considerations Used in the LLMW Accident Analysis . . . . . D-272
D.3.5.7 Results Tables for the Risk Analysis of Potential LLMW Accidents . . . . . D-273
D.3.5.8 Summary of the LLMW Accident Analysis Results . . . . . D-314
D.3.5.8.1 Risks to the Offsite Population From LLMW Accidents . . . . . D-314
D.3.5.8.2 Risks to the Noninvolved Worker Population From LLMW Accidents . . . . . D-316
D.3.5.8.3 Risks to the Maximally Exposed Noninvolved Worker and Maximally Exposed Offsite Individual From LLMW Accidents . . . . . D-317
D.3.5.8.4 Risks to Waste Management Workers From LLMW Accidents . . . . . D-319
D.3.5.9 Risks to the Hypothetical Intruder From LLMW Disposal . . . . . D-320
D.3.5.9.1 Results of the Human Health Risk Analysis for the Intruder . . . . . D-325
D.4 Uncertainty . . . . . D-326
D.4.1 Treatment and Storage Sites . . . . . D-328
D.4.1.1 Radionuclides . . . . . D-329
D.4.1.1.1 Sensitivity Analysis of GENII . . . . . D-329
D.4.1.1.2 Uncertainty Analysis . . . . . D-333
D.4.1.2 Hazardous Chemicals . . . . . D-334
D.4.1.3 Conclusion for Treatment and Storage Sites . . . . . D-334
D.4.2 Disposal Sites . . . . . D-335
D.4.2.1 Conclusion for Disposal Sites . . . . . D-337
D.4.3 Waste Management Workers . . . . . D-338
D.4.3.1 Conclusion for Worker Risk . . . . . D-340
D.5 Models Used in the PEIS Human Health Risk Evaluation . . . . . D-340
References . . . . . D-344

**Tables**


Table D.2–1 Preliminary Surface Water Analysis Results for Radionuclides . . . . . D–11
Table D.2–2 Preliminary Surface Water Analysis Results for Chemicals . . . . . D–11
Table D.2–3 ICRP Radiological Risk Factors Used in the PEIS Human Health Risk Evaluation . . . . . D–31
Table D.3.1–1 PEIS Waste Consolidation Alternatives for HLW . . . . . D–45
Table D.3.1–2 Summary of Programwide Risks Associated With Routine Management of HLW: Risks to Worker Population Under Storage Case 1, by Alternative . . . . . D–47
Table D.3.1–3 Programwide Risks Associated With Managing HLW Under Storage Case 1 of the No Action Alternative, by Health Endpoint . . . . . D–47
Table D.3.1–4 Programwide Risks Associated With Managing HLW Under Storage Case 1 of the Decentralized Alternative, by Health Endpoint . . . . D–47
Table D.3.1–5 Programwide Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 1, by Health Endpoint . . . . . D–48
Table D.3.1–6 Programwide Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 2, by Health Endpoint . . . . . D–48
Table D.3.1–7 Programwide Risks Associated With Managing HLW Under Storage Case 1 of the Centralized Alternative, by Health Endpoint . . . . . D–48
Table D.3.1–8 Risks Associated With Managing HLW Under Storage Case 1 of the No Action Alternative, by Site . . . . . D–49
Table D.3.1–9 Risks Associated With Managing HLW Under Storage Case 1 of the Decentralized Alternative, by Site . . . . . D–49
Table D.3.1–10 Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 1, by Site . . . . . D–49
Table D.3.1–11 Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 2, by Site . . . . . D–50
Table D.3.1–12 Risks Associated With Managing HLW Under Storage Case 1 of the Centralized Alternative, by Site . . . . . D–50
Table D.3.1–13 Storage Case 2: Incremental Annual Exposure Risks Associated With Storage Beyond 2015, in Risk per Year . . . . . D–50
Table D.3.1–14 Storage Case 2: Incremental Annual Operational Risks Associated With Storage Beyond 2015, in Risk per Year . . . . . D–51
Table D.3.1–15 Storage Case 2: Additional Loading, Unloading, and Construction Risks at Hanford . . . . . D–51
Table D.3.1–16 Summary of Risks From Potential HLW Accidents, by Accident Type and Site . . . . . D–54
Table D.3.1–17 Size of Offsite, Noninvolved Worker, and Worker Populations Affected by the Risks From Potential HLW Storage Accidents, by Site . . . . . D–54

Table D.3.1–18 HLW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population, by Accident Type and Site . . . . . D–54
Table D.3.2–1 PEIS Alternatives for LLW . . . . . D–57
Table D.3.2–2 Summary of Programwide Risks Associated With Treatment of LLW: Risks to Total Populations, by Alternative . . . . . D–62
Table D.3.2–3 Summary of Programwide Risks Associated With Disposal of LLW: Risks to Hypothetical Farm Family and Waste Management Workers, by Alternative . . . . . D–63
Table D.3.2–4 Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of LLW, by Alternative . . . . . D–64
Table D.3.2–5 Summary of Programwide Risks Associated With Treatment of LLW: Risks to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative . . . . . D–64
Table D.3.2–6 Radionuclide Contributing the Highest Risk of Cancer Fatality to the Offsite Population for LLW Treatment, by Alternative and Site . . . . . D–65
Table D.3.2–7 Programwide Risks Associated With Treatment of LLW Under the No Action Alternative, by Health Endpoint . . . . . D–66
Table D.3.2–8 Programwide Risks Associated With Treatment of LLW Under the Decentralized Alternative, by Health Endpoint . . . . . D–67
Table D.3.2–9 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 1, by Health Endpoint . . . . . D–68
Table D.3.2–10 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 3, by Health Endpoint . . . . . D–69
Table D.3.2–11 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 6, by Health Endpoint . . . . . D–70
Table D.3.2–12 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 7, by Health Endpoint . . . . . D–71
Table D.3.2–13 Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 1, by Health Endpoint . . . . . D–72
Table D.3.2–14 Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 2, by Health Endpoint . . . . . D–73
Table D.3.2–15 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 2, by Health Endpoint . . . . . D–74
Table D.3.2–16 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 4, by Health Endpoint . . . . . D–75
Table D.3.2–17 Programwide Risks Associated With Treatment of LLW Under Centralized Alternatives 3 and 4, by Health Endpoint . . . . . D–76

Table D.3.2–18 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 5, by Health Endpoint . . . . . D–77
Table D.3.2–19 Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 5, by Health Endpoint . . . . . D–78
Table D.3.2–20 Programwide Risks Associated With Treatment of LLW Under the No Action Alternative, by Site . . . . . D–79
Table D.3.2–21 Programwide Risks Associated With Treatment of LLW Under the Decentralized Alternative, by Site . . . . . D–80
Table D.3.2–22 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 1, by Site . . . . . D–81
Table D.3.2–23 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 3, by Site . . . . . D–82
Table D.3.2–24 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 6, by Site . . . . . D–83
Table D.3.2–25 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 7, by Site . . . . . D–84
Table D.3.2–26 Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 1, by Site . . . . . D–85
Table D.3.2–27 Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 2, by Site . . . . . D–86
Table D.3.2–28 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 2, by Site . . . . . D–87
Table D.3.2–29 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 4, by Site . . . . . D–88
Table D.3.2–30 Programwide Risks Associated With Treatment of LLW Under Centralized Alternatives 3 and 4, by Site . . . . . D–90
Table D.3.2–31 Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 5, by Site . . . . . D–92
Table D.3.2–32 Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 5, by Site . . . . . D–94
Table D.3.2–33 Programwide Risks Associated With Disposal of LLW Under the No Action Alternative, by Health Endpoint . . . . . D–96
Table D.3.2–34 Programwide Risks Associated With Disposal of LLW Under the Decentralized Alternative, by Health Endpoint . . . . . D–96
Table D.3.2–35 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 1, by Health Endpoint . . . . . D–97
Table D.3.2–36 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 3, by Health Endpoint . . . . . D–97
Table D.3.2–37 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 6, by Health Endpoint . . . . . D–98

Table D.3.2–38 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 7, by Health Endpoint . . . . . D–98
Table D.3.2–39 Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 1, by Health Endpoint . . . . . D–99
Table D.3.2–40 Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 2, by Health Endpoint . . . . . D–99
Table D.3.2–41 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 2, by Health Endpoint . . . . . D–100
Table D.3.2–42 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 4, by Health Endpoint . . . . . D–100
Table D.3.2–43 Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 3, by Health Endpoint . . . . . D–101
Table D.3.2–44 Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 4, by Health Endpoint . . . . . D–101
Table D.3.2–45 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 5, by Health Endpoint . . . . . D–102
Table D.3.2–46 Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 5, by Health Endpoint . . . . . D–102
Table D.3.2–47 Programwide Risks Associated With Disposal of LLW Under the No Action Alternative, by Site . . . . . D–103
Table D.3.2-48 Programwide Risks Associated With Disposal of LLW Under the Decentralized Alternative, by Site . . . . . D–103
Table D.3.2–49 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 1, by Site . . . . . D–104
Table D.3.2–50 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 3, by Site . . . . . D–104
Table D.3.2–51 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 6, by Site . . . . . D–105
Table D.3.2–52 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 7, by Site . . . . . D–105
Table D.3.2–53 Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 1, by Site . . . . . D–105
Table D.3.2–54 Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 2, by Site . . . . . D–106
Table D.3.2–55 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 2, by Site . . . . . D–106
Table D.3.2–56 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 4, by Site . . . . . D–107
Table D.3.2–57 Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 3, by Site . . . . . D–107

Table D.3.2–58 Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 4, by Site . . . . . D–108
Table D.3.2–59 Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 5, by Site . . . . . D–108
Table D.3.2–60 Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 5, by Site . . . . . D–109
Table D.3.2–61 Risks From Potential Maximum Reasonably Foreseeable LLW Treatment Facility Accidents, by Alternative and Site . . . . . D–119
Table D.3.2–62 Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Potential LLW Treatment Accidents, by Site . . . . . D–119
Table D.3.2–63 Accident Risks Associated With LLW Treatment at INEL Under the No Action Alternative, by Accident Type . . . . . D–120
Table D.3.2–64 Accident Risks Associated With LLW Treatment at SRS Under the No Action Alternative, by Accident Type . . . . . D–120
Table D.3.2–65 Accident Risks Associated With LLW Treatment at FEMP Under Regionalized Alternative 2, by Accident Type . . . . . D–121
Table D.3.2–66 Accident Risks Associated With LLW Treatment at Hanford Under Regionalized Alternative 2, by Accident Type . . . . . D–121
Table D.3.2–67 Accident Risks Associated With LLW Treatment at INEL Under Regionalized Alternative 2, by Accident Type . . . . . D–122
Table D.3.2–68 Accident Risks Associated With LLW Treatment at LLNL Under Regionalized Alternative 2, by Accident Type . . . . . D–122
Table D.3.2–69 Accident Risks Associated With LLW Treatment at LANL Under Regionalized Alternative 2, by Accident Type . . . . . D–123
Table D.3.2–70 Accident Risks Associated With LLW Treatment at ORR Under Regionalized Alternative 2, by Accident Type . . . . . D–123
Table D.3.2–71 Accident Risks Associated With LLW Treatment at PGDP Under Regionalized Alternative 2, by Accident Type . . . . . D–124
Table D.3.2–72 Accident Risks Associated With LLW Treatment at PORTS Under Regionalized Alternative 2, by Accident Type . . . . . D–124
Table D.3.2–73 Accident Risks Associated With LLW Treatment at RFETS Under Regionalized Alternative 2, by Accident Type . . . . . D–125
Table D.3.2–74 Accident Risks Associated With LLW Treatment at SRS Under Regionalized Alternative 2, by Accident Type . . . . . D–125
Table D.3.2–75 Accident Risks Associated With LLW Treatment at Hanford Under Centralized Alternative 5, by Accident Type . . . . . D–126
Table D.3.2–76 Summary Table for the Intruder Scenario for LLW (100 years) . . . . . D–130
Table D.3.2–77 Summary Table for the Intruder Scenario for LLW (300 years) . . . . . D–130

Table D.3.2–78 Intruder Scenario Risk Results for the Decentralized Alternative (100 years) . . . . . D–131
Table D.3.2–79 Intruder Scenario Risk Results for the Decentralized Alternative (300 years) . . . . . D–131
Table D.3.2–80 Intruder Scenario Risk Results for Regionalized Alternative 3 (100 years) . . . . . D–132
Table D.3.2–81 Intruder Scenario Risk Results for Regionalized Alternative 3 (300 years) . . . . . D–132
Table D.3.2–82 Intruder Scenario Risk Results for Centralized Alternative 1 (100 years) . . . . . D–132
Table D.3.2–83 Intruder Scenario Risk Results for Centralized Alternative 1 (300 years) . . . . . D–132
Table D.3.3–1 PEIS Alternatives for HW . . . . . D–137
Table D.3.3–2 HW Source Term Constituents Derived From Analysis of Deer Park, Texas, Incinerator Flue Gases . . . . . D–137
Table D.3.3–3 Summary of Programwide Risks Associated With Routine Management of HW: Risks to Total Populations, by Alternative . . . . . D–139
Table D.3.3–4 Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by the Risks From Routine Management of HW, by Alternative . . . . . D–140
Table D.3.3–5 Summary of Programwide Risks Associated With Managing HW to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative . . . . . D–140
Table D.3.3–6 Programwide Risks Associated With the Routine Management of HW Under the No Action Alternative, by Health Endpoint . . . . . D–141
Table D.3.3–7 Programwide Risks Associated With the Routine Management of HW Under Regionalized Alternative 1, by Health Endpoint . . . . . D–142
Table D.3.3–8 Programwide Risks Associated With the Routine Management of HW Under Regionalized Alternative 2, by Health Endpoint . . . . . D–143
Table D.3.3–9 Risks Associated With the Routine Management of HW Under the No Action Alternative, by Site . . . . . D–144
Table D.3.3–10 Risks Associated With the Routine Management of HW Under Regionalized Alternative 1, by Site . . . . . D–144
Table D.3.3–11 Risks Associated With the Routine Management of HW Under Regionalized Alternative 2, by Site . . . . . D–145
Table D.3.3–12 Constituents in HW Contributing the Highest Risk of Cancer Incidence to the Offsite Population at Each Site, by Alternative . . . . . D–145
Table D.3.3–13 Summary of Single-Drum Accident Scenarios for HW . . . . . D–151
Table D.3.3–14 Chemical Surrogates Used in Risk Analysis for Potential HW Accidents . . . . . D–154

Table D.3.3–15 Summary of Risks to the Offsite and Waste Management Worker Populations From Potential Single-Drum HW Accidents, by Alternative and Site . . . . . D–155
Table D.3.3–16 Risks Associated With Potential Facilitywide HW Storage Accidents Under Regionalized Alternative 1, by Accident and Site . . . . . D–156
Table D.3.3–17 Risks Associated With Potential Facilitywide HW Storage Accidents Under Regionalized Alternative 2, by Accident and Site . . . . . D–157
Table D.3.3–18 Risks Associated With Potential Facilitywide HW Treatment Accidents Under Regionalized Alternative 1, by Accident and Site . . . . . D–158
Table D.3.3–19 Risks Associated With Potential Facilitywide HW Treatment Accidents Under Regionalized Alternative 2, by Accident and Site . . . . . D–159
Table D.3.3–20 Size of Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Potential HW Treatment and Storage Accidents, by Site . . . . . D–159
Table D.3.4–1 PEIS Alternatives for CH-TRUW . . . . . D–170
Table D.3.4–2 PEIS Consolidation and Treatment Strategies for CH-TRUW . . . . . D–171
Table D.3.4–3 Summary of Programwide Risks Associated With Routine Management of CH-TRUW: Risks to Total Populations, by Alternative . . . . . D–174
Table D.3.4–4 Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of CH-TRUW, by Alternative . . . . . D–174
Table D.3.4–5 Summary of Programwide Risks Associated With Routine Management of CH-TRUW: Risks to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative . . . . . D–174
Table D.3.4–6 Programwide Risks Associated With Managing CH-TRUW Under the No Action Alternative . . . . . D–175
Table D.3.4–7 Programwide Risks Associated With Managing CH-TRUW Under the Decentralized Alternative . . . . . D–176
Table D.3.4–8 Programwide Risks Associated With Managing CH-TRUW Under Regionalized Alternative 1 . . . . . D–177
Table D.3.4–9 Programwide Risks Associated With Managing CH-TRUW Under Regionalized Alternative 2 . . . . . D–178
Table D.3.4–10 Programwide Risks Associated With Managing CH-TRUW Under Regionalized Alternative 3 . . . . . D–179
Table D.3.4–11 Programwide Risks Associated With Managing CH-TRUW Under the Centralized Alternative . . . . . D–180

Table D.3.4–12 Risks Associated With Managing CH-TRUW Under the No Action Alternative, by Site . . . . . D–181
Table D.3.4–13 Risks Associated With Managing CH-TRUW Under the Decentralized Alternative, by Site . . . . . D–182
Table D.3.4–14 Risks Associated With Managing CH-TRUW Under Regionalized Alternative 1, by Site . . . . . D–183
Table D.3.4–15 Risks Associated With Managing CH-TRUW Under Regionalized Alternative 2, by Site . . . . . D–184
Table D.3.4–16 Risks Associated With Managing CH-TRUW Under Regionalized Alternative 3, by Site . . . . . D–185
Table D.3.4–17 Risks Associated With Managing CH-TRUW Under the Centralized Alternative, by Site . . . . . D–186
Table D.3.4–18 CH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population at Each Site, by Alternative . . . . . D–187
Table D.3.4–19 Population Distribution Around Hanford on the Basis of the 1990 U.S. Census . . . . . D–192
Table D.3.4–20 Population Distribution Around the Waste Isolation Pilot Plant on the Basis of the 1990 U.S. Census . . . . . D–193
Table D.3.4–21 PEIS Alternatives for RH-TRUW . . . . . D–198
Table D.3.4–22 PEIS Consolidation and Treatment Strategies for RH-TRUW . . . . . D–198
Table D.3.4–23 Summary of Programwide Risks Associated With Routine Management of RH-TRUW: Risks to Total Populations, by Alternative . . . . . D–200
Table D.3.4–24 Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of RH-TRUW, by Alternative . . . . . D–200
Table D.3.4–25 Summary of Programwide Risks Associated With Routine Management of RH-TRUW: Risks To the Maximally Exposed Offsite Individual and Maximally Exposed Noninvolved Worker, by Alternative . . . . . D–200
Table D.3.4–26 Programwide Risks Associated With Treatment of RH-TRUW Under the No Action Alternative, by Health Endpoint . . . . . D–201
Table D.3.4–27 Programwide Risks Associated With Treatment of RH-TRUW Under the Decentralized Alternative, by Health Endpoint . . . . . D–202
Table D.3.4–28 Programwide Risks Associated With Treatment of RH-TRUW Under Regionalized Alternative 1, by Health Endpoint . . . . . D–203
Table D.3.4–29 Programwide Risks Associated With Treatment of RH-TRUW Under Regionalized Alternatives 2 and 3 and the Centralized Alternative, by Health Endpoint . . . . . D–204
Table D.3.4–30 Risks Associated With Treatment of RH-TRUW Under the No Action Alternative, by Site . . . . . D–205

Table D.3.4–31 Risks Associated With Treatment of RH-TRUW Under the Decentralized Alternative, by Site . . . . . D–205
Table D.3.4–32 Risks Associated With Treatment of RH-TRUW Under Regionalized Alternative 1, by Site . . . . . D–206
Table D.3.4–33 Risks Associated With Treatment of RH-TRUW Under Regionalized Alternatives 2 and 3 and the Centralized Alternative, by Site . . . . . D–206
Table D.3.4–34 RH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population at Each Site, by Alternative . . . . . D–207
Table D.3.4–35 Radionuclide-Related Risks From Potential Maximum Reasonably Foreseeable CH-TRUW Treatment Facility Accidents, by Alternative and Site . . . . . D–214
Table D.3.4–36 Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Potential CH-TRUW Treatment Accidents, by Site . . . . . D–214
Table D.3.4–37 Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at Hanford Under Regionalized Alternative 2, by Accident Type . . . . . D–215
Table D.3.4–38 Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at INEL Under Regionalized Alternative 2, by Accident Type . . . . . D–215
Table D.3.4–39 Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at LANL Under Regionalized Alternative 2, by Accident Type . . . . . D–216
Table D.3.4–40 Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at RFETS Under Regionalized Alternative 3, by Accident Type . . . . . D–216
Table D.3.4-41 Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at SRS Under Regionalized Alternative 2, by Accident Type . . . . . D–217
Table D.3.4–42 Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at Hanford Under Regionalized Alternative 3, by Accident Type . . . . . D–217
Table D.3.4-43 Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at INEL Under Regionalized Alternative 3, by Accident Type . . . . . D–218
Table D.3.4–44 Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at SRS Under Regionalized Alternative 3, by Accident Type . . . . . D–218

Table D.3.4–45 Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at WIPP Under the Centralized Alternative, by Accident Type . . . . . D–219
Table D.3.4–46 Radionuclide-Related Risks from Potential Maximum Reasonably Foreseeable RH-TRUW Treatment Facility Accidents, by Alternative and Site . . . . . D–224
Table D.3.4–47 Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Potential RH-TRUW Treatment Accidents, by Site . . . . . D–225
Table D.3.4–48 Radionuclide-Related Accident Risks Associated With RH-TRUW Treatment at Hanford Under the Regionalized Alternative 2, 3, and Centralized Alternatives, by Accident Type . . . . . D–225
Table D.3.4-49 Radionuclide-Related Accident Risks Associated With RH-TRUW Treatment at ORNL Under the Regionalized Alternative 2, 3, and Centralized Alternatives, by Accident Type . . . . . D–226
Table D.3.5–1 PEIS Alternatives for LLMW . . . . . D–233
Table D.3.5–2 Summary of Programwide Risks Associated With Treatment of LLMW: Risks to Total Populations, by Alternative . . . . . D–236
Table D.3.5–3 Summary of Programwide Risks Associated With Disposal of LLMW: Risks to Hypothetical Farm Family and Waste Management Workers, by Alternative . . . . . D–236
Table D.3.5–4 Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of LLMW, by Alternative . . . . . D–237
Table D.3.5–5 Summary of Programwide Risks Associated With Treatment of LLMW: Risks to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative . . . . . D–237
Table D.3.5–6 Radionuclide Contributing the Highest Risk of Cancer Fatality to the Offsite Population for LLMW Treatment, by Alternative and Site . . . . . D–238
Table D.3.5–7 Programwide Risks Associated With Treatment of LLMW Under the No Action Alternative, by Health Endpoint . . . . . D–239
Table D.3.5–8 Programwide Risks Associated With Treatment of LLMW Under the Decentralized Alternative, by Health Endpoint . . . . . D–240
Table D.3.5–9 Programwide Risks Associated With Treatment of LLMW Under Regionalized Alternative 1, by Health Endpoint . . . . . D–241
Table D.3.5–10 Programwide Risks Associated With Treatment of LLMW Under Regionalized Alternative 2, by Health Endpoint . . . . . D–242
Table D.3.5–11 Programwide Risks Associated With Treatment of LLMW Under Regionalized Alternative 3, by Health Endpoint . . . . . D–243

Table D.3.5–12 Programwide Risks Associated With Treatment of LLMW Under Regionalized Alternative 4, by Health Endpoint . . . . . D–244
Table D.3.5–13 Programwide Risks Associated With Treatment of LLMW Under the Centralized Alternative, by Health Endpoint . . . . . D–245
Table D.3.5–14 Programwide Risks Associated With Treatment of RH-LLMW Under Each Alternative Except No Action, by Health Endpoint . . . . . D–246
Table D.3.5–15 Risks Associated With Treatment of LLMW Under the No Action Alternative, by Site . . . . . D–247
Table D.3.5–16 Risks Associated With Treatment of LLMW Under the Decentralized Alternative, by Site . . . . . D–248
Table D.3.5–17 Risks Associated With Treatment of LLMW Under the Regionalized Alternative 1, by Site . . . . . D–249
Table D.3.5–18 Risks Associated With Treatment of LLMW Under Regionalized Alternative 2, by Site . . . . . D–250
Table D.3.5–19 Risks Associated With Treatment of LLMW Under Regionalized Alternative 3, by Site . . . . . D–251
Table D.3.5–20 Risks Associated With Treatment of LLMW Under Regionalized Alternative 4, by Site . . . . . D–252
Table D.3.5–21 Risks Associated With Treatment of LLMW Under the Centralized Alternative, by Site . . . . . D–253
Table D.3.5–22 Risks Associated With Treatment of RH-LLMW Under Each Alternative Except No Action, by Site . . . . . D–254
Table D.3.5–23 Programwide Risks Associated With Disposal of LLMW Under the Decentralized Alternative, by Health Endpoint . . . . . D–254
Table D.3.5–24 Programwide Risks Associated With Disposal of LLMW Under Regionalized Alternative 1, by Health Endpoint . . . . . D–255
Table D.3.5–25 Programwide Risks Associated With Disposal of LLMW Under Regionalized Alternative 2, by Health Endpoint . . . . . D–255
Table D.3.5–26 Programwide Risks Associated With Disposal of LLMW Under Regionalized Alternative 3, by Health Endpoint . . . . . D–256
Table D.3.5–27 Programwide Risks Associated With Disposal of LLMW Under Regionalized Alternative 4, by Health Endpoint . . . . . D–256
Table D.3.5–28 Programwide Risks Associated With Disposal of LLMW Under the Centralized Alternative, by Health Endpoint . . . . . D–257
Table D.3.5–29 Programwide Risks Associated With Disposal of RH-LLMW Under Each Alternative Except No Action, by Health Endpoint . . . . . D–257
Table D.3.5–30 Risks Associated With Disposal of LLMW Under the Decentralized Alternative, by Site . . . . . D–258
Table D.3.5–31 Risks Associated With Disposal of LLMW Under Regionalized Alternative 1, by Site . . . . . D–259

Table D.3.5–32 Risks Associated With Disposal of LLMW Under Regionalized Alternative 2, by Site . . . . . D–259
Table D.3.5–33 Risks Associated With Disposal of LLMW Under Regionalized Alternative 3, by Site . . . . . D–260
Table D.3.5–34 Risks Associated With Disposal of LLMW Under Regionalized Alternative 4, by Site . . . . . D–260
Table D.3.5–35 Risks Associated With Disposal of LLMW Under the Centralized Alternative, by Site . . . . . D–261
Table D.3.5–36 Risks Associated With Disposal of RH-LLMW Under Each Alternative Except No Action, by Site . . . . . D–261
Table D.3.5–37 Radionuclide-Related Risks From Potential Maximum Reasonably Foreseeable LLMW Treatment Facility Accidents, by Alternative and Site . . . . . D–274
Table D.3.5–38 Chemical-Related Risks From Potential Maximum Reasonably Foreseeable LLMW Treatment Facility Accidents, by Alternative and Site . . . . . D–275
Table D.3.5–39 Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the No Action Alternative, by Accident Type . . . . . D–277
Table D.3.5–40 Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the No Action Alternative, by Accident Type . . . . . D–277
Table D.3.5–41 Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the No Action Alternative, by Accident Type . . . . . D–278
Table D.3.5–42 Radionuclide-Related Accident Risks Associated With LLMW Treatment at ANL-E Under the Decentralized Alternative, by Accident Type . . . . . D–278
Table D.3.5–43 Radionuclide-Related Accident Risks Associated With LLMW Treatment at BNL Under the Decentralized Alternative, by Accident Type . . . . . D–279
Table D.3.5–44 Radionuclide-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Decentralized Alternative, by Accident Type . . . . . D–279
Table D.3.5–45 Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Decentralized Alternative, by Accident Type . . . . . D–280
Table D.3.5–46 Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Decentralized Alternative, by Accident Type . . . . . D–280

Table D.3.5–47 Radionuclide-Related Accident Risks Associated With LLMW Treatment at KAPL-K Under the Decentralized Alternative, by Accident Type . . . . . D–281
Table D.3.5–48 Radionuclide-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Decentralized Alternative, by Accident Type . . . . . D–281
Table D.3.5–49 Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Decentralized Alternative, by Accident Type . . . . . D–282
Table D.3.5–50 Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the Decentralized Alternative, by Accident Type . . . . . D–282
Table D.3.5–51 Radionuclide-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Decentralized Alternative, by Accident Type . . . . . D–283
Table D.3.5–52 Radionuclide-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Decentralized Alternative, by Accident Type . . . . . D–283
Table D.3.5–53 Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Decentralized Alternative, by Accident Type . . . . . D–284
Table D.3.5–54 Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Decentralized Alternative, by Accident Type . . . . . D–284
Table D.3.5–55 Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 1, by Accident Type . . . . . D–285
Table D.3.5–56 Radionuclide-Related Accident Risks Associated With LLMW Treatment at LLNL Under Regionalized Alternative 1, by Accident Type . . . . . D–285
Table D.3.5–57 Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 1, by Accident Type . . . . . D–286
Table D.3.5–58 Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under Regionalized Alternative 1, by Accident Type . . . . . D–286
Table D.3.5–59 Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 1, by Accident Type . . . . . D–287

Table D.3.5–60 Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under Regionalized Alternative 2, by Accident Type . . . . . D–287
Table D.3.5–61 Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 2, by Accident Type . . . . . D–288
Table D.3.5–62 Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under Regionalized Alternative 2, by Accident Type . . . . . D–289
Table D.3.5–63 Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under Regionalized Alternative 2, by Accident Type . . . . . D–289
Table D.3.5–64 Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under Regionalized Alternative 2, by Accident Type . . . . . D–290
Table D.3.5–65 Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 2, by Accident Type . . . . . D–291
Table D.3.5–66 Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under Regionalized Alternative 4, by Accident Type . . . . . D–291
Table D.3.5–67 Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 4, by Accident Type . . . . . D–292
Table D.3.5–68 Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under Regionalized Alternative 4, by Accident Type . . . . . D–292
Table D.3.5–69 Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 4, by Accident Type . . . . . D–293
Table D.3.5–70 Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Centralized Alternative, by Accident Type . . . . . D–294
Table D.3.5–71 Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the No Action Alternative, by Accident Type . . . . . D–294
Table D.3.5–72 Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the No Action Alternative, by Accident Type . . . . . D–295

Table D.3.5–73 Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the No Action Alternative, by Accident Type . . . . . D–295
Table D.3.5–74 Chemical-Related Accident Risks Associated With LLMW Treatment at ANL-E Under the Decentralized Alternative, by Accident Type . . . . . D–295
Table D.3.5–75 Chemical-Related Accident Risks Associated With LLMW Treatment at BNL Under the Decentralized Alternative, by Accident Type . . . . . D–296
Table D.3.5–76 Chemical-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Decentralized Alternative, by Accident Type . . . . . D–296
Table D.3.5–77 Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Decentralized Alternative, by Accident Type . . . . . D–296
Table D.3.5–78 Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Decentralized Alternative, by Accident Type . . . . . D–297
Table D.3.5–79 Chemical-Related Accident Risks Associated With LLMW Treatment at KCP Under the Decentralized Alternative, by Accident Type . . . . . D–297
Table D.3.5–80 Chemical-Related Accident Risks Associated With LLMW Treatment at KAPL-K Under the Decentralized Alternative, by Accident Type . . . . . D–298
Table D.3.5–81 Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under the Decentralized Alternative, by Accident Type . . . . . D–298
Table D.3.5–82 Chemical-Related Accident Risks Associated With LLMW Treatment at LBL Under the Decentralized Alternative, by Accident Type . . . . . D–299
Table D.3.5–83 Chemical-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Decentralized Alternative, by Accident Type . . . . . D–299
Table D.3.5–84 Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Decentralized Alternative, by Accident Type . . . . . D–300
Table D.3.5–85 Chemical-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Decentralized Alternative, by Accident Type . . . . . D–300

Table D.3.5–86 Chemical-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Decentralized Alternative, by Accident Type . . . . . D–300
Table D.3.5–87 Chemical-Related Accident Risks Associated With LLMW Treatment at PORTS Under the Decentralized Alternative, by Accident Type . . . . . D–301
Table D.3.5–88 Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Decentralized Alternative, by Accident Type . . . . . D–301
Table D.3.5–89 Chemical-Related Accident Risks Associated With LLMW Treatment at SNL-NM Under the Decentralized Alternative, by Accident Type . . . . . D–301
Table D.3.5–90 Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Decentralized Alternative, by Accident Type . . . . . D–302
Table D.3.5–91 Chemical-Related Accident Risks Associated With LLMW Treatment at FEMP Under Regionalized Alternative 1, by Accident Type . . . . . D–302
Table D.3.5–92 Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under Regionalized Alternative 1, by Accident Type . . . . . D–303
Table D.3.5–93 Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 1, by Accident Type . . . . . D–303
Table D.3.5–94 Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under Regionalized Alternative 1, by Accident Type . . . . . D–304
Table D.3.5–95 Chemical-Related Accident Risks Associated With LLMW Treatment at LLNL Under Regionalized Alternative 1, by Accident Type . . . . . D–304
Table D.3.5–96 Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under Regionalized Alternative 1, by Accident Type . . . . . D–305
Table D.3.5–97 Chemical-Related Accident Risks Associated With LLMW Treatment at Pantex Under Regionalized Alternative 1, by Accident Type . . . . . D–305
Table D.3.5–98 Chemical-Related Accident Risks Associated With LLMW Treatment at PGDP Under Regionalized Alternative 1, by Accident Type . . . . . D–306

Table D.3.5-99 Chemical-Related Accident Risks Associated With LLMW Treatment at PORTS Under Regionalized Alternative 1, by Accident Type . . . . . D-306
Table D.3.5-100 Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under Regionalized Alternative 1, by Accident Type . . . . . D-307
Table D.3.5-101 Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 1, by Accident Type . . . . . D-307
Table D.3.5-102 Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under Regionalized Alternative 2, by Accident Type . . . . . D-308
Table D.3.5-103 Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 2, by Accident Type . . . . . D-308
Table D.3.5-104 Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under Regionalized Alternative 2, by Accident Type . . . . . D-309
Table D.3.5-105 Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under Regionalized Alternative 2, by Accident Type . . . . . D-309
Table D.3.5-106 Chemical-Related Accident Risks Associated With LLMW Treatment at PORTS Under Regionalized Alternative 2, by Accident Type . . . . . D-310
Table D.3.5-107 Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under Regionalized Alternative 2, by Accident Type . . . . . D-310
Table D.3.5-108 Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 2, by Accident Type . . . . . D-311
Table D.3.5-109 Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under Regionalized Alternative 4, by Accident Type . . . . . D-311
Table D.3.5-110 Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 4, by Accident Type . . . . . D-312
Table D.3.5-111 Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under Regionalized Alternative 4, by Accident Type . . . . . D-312

Table D.3.5–112 Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 4, by Accident Type . . . . . D–313
Table D.3.5–113 Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Centralized Alternative, by Accident Type . . . . . D–313
Table D.3.5–114 Summary Table for the Intruder Scenario for LLMW (100 years) . . . . . D–321
Table D.3.5–115 Summary Table for the Intruder Scenario for LLMW (300 years) . . . . . D–321
Table D.3.5–116 Intruder Scenario Risk Results for the Decentralized Alternative (100 years) . . . . . D–322
Table D.3.5–117 Intruder Scenario Risk Results for the Decentralized Alternative (300 years) . . . . . D–322
Table D.3.5–118 Intruder Scenario Risk Results for Regionalized Alternative 2 (100 years) . . . . . D–323
Table D.3.5–119 Intruder Scenario Risk Results for Regionalized Alternative 2 (300 years) . . . . . D–323
Table D.3.5–120 Intruder Scenario Risk Results for the Centralized Alternative (100 years) . . . . . D–324
Table D.3.5–121 Intruder Scenario Risk Results for the Centralized Alternative (300 years) . . . . . D–324
Table D.3.5–122 Intruder Scenario Risk Results for RH-LLMW (100 years) . . . . . D–325
Table D.3.5–123 Intruder Scenario Risk Results for RH-LLMW (300 years) . . . . . D–325
Table D.4–1 Descriptive Statistics for Chi/Q From ORR Meteorological Data . . . . . D–332
Table D.4–2 Results of GENII Sensitivity Study . . . . . D–332
Table D.4–3 Correlation Coefficients for Significant Variables . . . . . D–333
Table D.4–4 Descriptive Statistics for AEDE From the Uncertainty Analysis . . . . . D–334
Table D.4–5 Uncertainties of Risk Predictions via the Groundwater Pathway . . . . . D–337

## Figures

Figure D.2–1 Exposure Routes for the Offsite and Noninvolved Worker Populations for Treatment and Storage Activities . . . . . D–13
Figure D.2–2 Exposure Routes for Waste Management Workers for Routine Operations and Accidents During Waste Treatment and Storage . . . . . D–14
Figure D.2–3 Exposure Routes for the Intruder for Disposal Activities . . . . . D–15
Figure D.2–4 Exposure Routes for the Farm Family and Waste Management Workers for Disposal Activities . . . . . D–16

# Acronyms and Abbreviations

The following is a list of acronyms and abbreviations (including units of measure) used in this appendix.

**Acronyms**

| | |
|---|---|
| ACGIH | American Conference of Governmental Industrial Hygienists |
| AEDE | annual effective dose equivalent |
| ALARA | as low as reasonably achievable |
| ANL | Argonne National Laboratory |
| ANL-E | Argonne National Laboratory-East |
| ANL-W | Argonne National Laboratory-West |
| ANSI | American National Standards Institute |
| BNL | Brookhaven National Laboratory |
| CEDE | committed effective dose equivalent |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CF | cancer fatality |
| CFR | *Code of Federal Regulations* (indicating citation from) |
| CH | contact-handled |
| CI | cancer incidence |
| C&OF | construction and operational fatalities |
| D&D | decontamination and decommissioning |
| DITTY | the Dose-in-Ten-Thousand-Years computational model |
| DOE | U.S. Department of Energy |
| DUST | Disposal Unit Source Term computational model |
| EDE | effective dose equivalent |
| EI | exposure index |
| EIS | environmental impact statement |
| EPA | U.S. Environmental Protection Agency |
| ER | environmental restoration |
| ETEC | Energy Technology Engineering Center |
| FEMP | Fernald Environmental Management Project |
| Fermi | Fermi National Accelerator Laboratory |
| FTE | full-time equivalent |
| GENII | Generation II of the Hanford Environmental Radiation Dosimetry Software System |
| GENII–S | Sensitivity and Uncertainty Analysis portion of the GENII computational model |
| GTCC–LLW | greater-than-Class-C low-level waste |
| Hanford | Hanford Site |
| HEAST | Health Effects Assessment Summary Tables |

| | |
|---|---|
| HI | hazard index |
| HLW | high-level waste |
| HW | hazardous waste |
| ICRP | International Commission on Radiological Protection |
| IDLH | immediately dangerous to life and health |
| INEL | Idaho National Engineering Laboratory |
| INEXPLC | computational model for simulating close-in atmospheric dispersion, explosive releases, and particle deposition |
| IRIS | Integrated Risk Information System |
| ISC2 | Industrial Source Complex Dispersion Models, Version 2 |
| ITRI | Inhalation Toxicology Research Institute |
| K-25 | Oak Ridge K-25 Site |
| KAPL-K | Knolls Atomic Power Laboratory–Kesselring |
| KCP | Kansas City Plant |
| LANL | Los Alamos National Laboratory |
| LBL | Lawrence Berkeley Laboratory |
| LDRs | land disposal restrictions |
| LLMW | low-level mixed waste |
| LLNL | Lawrence Livermore National Laboratory |
| LLW | low-level waste |
| MEI | maximally exposed individual |
| MEL | maximally exposed lifetime of the hypothetical farm family |
| MEPAS | Multimedia Environmental Pollutant Assessment System |
| NAS | National Academy of Sciences |
| NAS/NRC | National Academy of Sciences/National Research Council |
| NEPA | National Environmental Policy Act |
| NRC | U.S. Nuclear Regulatory Commision |
| NRF | Naval Reactor Facility |
| NTS | Nevada Test Site |
| ORISE | Oak Ridge Institute for Science and Education |
| ORNL | Oak Ridge National Laboratory |
| ORR | Oak Ridge Reservation |
| Pantex | Pantex Plant |
| PCB | polychlorinated biphenyl |
| PEIS | DOE *Draft Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* |
| PGDP | Paducah Gaseous Diffusion Plant |
| Pinellas | Pinellas Plant |
| PNNL | Battelle Pacific Northwest National Laboratory |
| PORTS | Portsmouth Gaseous Diffusion Plant |
| PRESTO | series of computational models for assessing the potential human health impacts from the disposal of low-level waste |

| | |
|---|---|
| RCRA | Resource Conservation and Recovery Act |
| RFETS | Rocky Flats Environmental Technology Site |
| RH | remote-handled |
| SNL-CA | Sandia National Laboratory (California) |
| SNL-NM | Sandia National Laboratories (New Mexico) |
| SRS | Savannah River Site |
| TLV | threshold limit value |
| TRUPACT II | Transuranic Package Transporter–II |
| TRUW | transuranic waste |
| TWA–TLV | time-weighted average threshold limit value |
| UofMO | University of Missouri (Columbia) |
| WIPP | Waste Isolation Pilot Plant |
| WIPP–WAC | Waste Isolation Pilot Plant Waste Acceptance Criteria |
| WM | of or pertaining to the DOE Waste Management Program |
| WVDP | West Valley Demonstration Project |
| Y-12 | Oak Ridge Y-12 Plant |

**Abbreviations**

| | |
|---|---|
| Am | americium |
| C | carbon |
| Ci | curie(s) |
| Cm | curium |
| $cm^2$ | square centimeter(s) |
| $cm^3$ | cubic centimeter(s) |
| Co | cobalt |
| Cs | cesium |
| d | day(s) |
| E | east |
| ENE | east-northeast |
| ESE | east-southeast |
| *Fed. Reg.* | *Federal Register* (indicating citation from) |
| $ft^3$ | cubic foot (feet) |
| g | gram(s) |
| gal | gallon(s) |
| h | hour(s) |
| H–3 | tritium |

| | |
|---|---|
| I | iodine |
| in. | inch |
| $K_d$ | sorption distribution coefficient (for contaminants in soil) |
| kg | kilogram(s) |
| km | kilometer(s) |
| L | liter(s) |
| m | meter(s) |
| $m^2$ | square meter(s) |
| $m^3$ | cubic meter(s) |
| mi | mile(s) |
| min | minute(s) |
| mph | mile(s) per hour |
| mrem | milliroentgen equivalent man |
| N | north |
| nCi | nanocurie(s) |
| NE | northeast |
| NNE | north-northeast |
| NNW | north-northwest |
| Np | neptunium |
| NW | northwest |
| P | phosphorus |
| pCi | picocurie(s) |
| Pu | plutonium |
| qt | quart(s) |
| rem | roentgen equivalent man |
| RfC | reference concentration |
| RfD | reference dose |
| Ru | ruthenium |
| S | south |
| S | sulfur |
| SE | southeast |
| Sr | strontium |
| SSE | south-southeast |
| SSW | south-southwest |
| SW | southwest |
| t | ton(s) |
| Tc | technetium |
| Th | thorium |
| U | uranium |

| | |
|---|---|
| W | west |
| WNW | west-northwest |
| WSW | west-southwest |
| | |
| Y | yttrium |
| yr | year(s) |
| yd | yard(s) |

# APPENDIX D
# Waste Management Facility Human Health Risk Estimates

## D.1 Introduction

This appendix summarizes the human health impacts posed by stationary sources of waste at U.S. Department of Energy (DOE) waste management facilities. The term "stationary source" refers to facilities that process, store, or dispose of various types of waste throughout the DOE complex, in contrast to waste transport. Waste transportation risks are discussed in Appendix E. Supplemental details of this human health risk assessment are available in a separate technical report (ORNL, 1996).

This appendix is organized as follows:

- Section D.1 defines the purpose and scope of the Waste Management (WM) Program human health risk evaluation including an overview of the five DOE WM Program waste types and waste consolidation alternatives.
- Section D.2 presents general information on the risk assessment process, including a discussion of the potentially exposed populations and health effects evaluated, assumptions used to calculate the risks to the affected populations and individuals, explanations of certain risk calculations, and directions on how to read and interpret the risk results that are presented in Section D.3.
- Section D.3 contains the human health risk evaluations for the five DOE WM Program waste types. It provides definitions of the wastes; identifies the waste consolidation alternatives evaluated; discusses the assumptions used in estimating the human health risks for routine waste management activities and potential accidents by waste type; presents a summary of the human health risk results for routine waste management activities and (where applicable) accidents by waste type; and identifies the waste consolidation options and contaminants that potentially pose the greatest and least risks to human health.
- Section D.4 describes the uncertainties associated with the waste management human health risk evaluation.
- Section D.5 presents a discussion of the mathematical models used to develop the human health risk estimates for this study.

A summary narrative explaining the health risk analysis methodologies for the reader interested in less technical information is presented in the Summary and in Chapter 5 of Volume I. Summarized results of

the risk analyses for each of the five waste types are presented in the Summary and in Chapters 6–10 of Volume I.

### D.1.1 Purpose of the Waste Management Human Health Risk Evaluation

The purpose of this human health risk evaluation is to provide projections of the health risks posed by the waste consolidation options being considered for DOE waste management facilities in this draft programmatic environmental impact statement (hereinafter called the PEIS). This information, in conjunction with other PEIS impacts (e.g., transportation risks, ecological risks, air, water, and socioeconomic impacts) and costs, is intended to aid in determining the advantages and disadvantages of the various waste consolidation options.

The risk estimates presented here are based on various assumptions, best available data, and data generated by fate and transport and exposure modeling (instead of data gathered by monitoring). This was necessary because monitored data were not consistently available for all sites and/or processes have not been demonstrated fully. To maintain consistency with current regulatory approaches to risk assessment, the methodologies used to estimate the various elements of risk for the PEIS were partially adapted from existing accepted risk assessment methods (NAS, 1983; EPA, 1989a, 1991a,b; ICRP, 1977, 1979, 1990) or developed specifically for the PEIS (ORNL, 1995a-c). While it is important to recognize the purpose and limitations of this assessment, the same assumptions and methodologies were applied uniformly to all sites. Therefore, when used on a *comparative* basis at the program level, these results should provide a relatively accurate overview of the risks posed by WM Program treatment, storage, and disposal activities. More detailed risk estimates for a particular DOE site should be performed when necessary in site-specific documents (e.g., environmental impact statements, environmental assessments, risk assessments).

### D.1.2 Waste Types Evaluated

Both existing and future waste management facilities were evaluated for the following waste types:

- High-level waste (HLW) (Section D.3.1)
- Low-level waste (LLW) (Section D.3.2)
- Hazardous waste (HW) (Section D.3.3)

- Transuranic waste (TRUW) (Section D.3.4)
- Low-level mixed waste (LLMW) (Section D.3.5)

The risk analysis for each waste type and site was performed based on data including (1) estimated rates of contaminant release to the air and/or the water in the water table (called "groundwater"), and (2) estimated waste processing rates (which determine a worker's hourly exposure). These two types of release rates are called "source terms." The source terms for the human health risk analysis were developed by Argonne National Laboratory (ANL) based on waste inventory information and characterization data, waste management module characterization information, and the definitions of the various PEIS alternatives. This process, as well as the source terms used in the analysis, are included in Appendix C and supporting technical reports by ANL (ANL, 1995a-e).

Health effects were not evaluated for spent nuclear fuel (from which HLW is derived) because its programmatic issues are assessed in a separate environmental impact statement (see further discussion of this in Chapter 1 of the PEIS). It is assumed that privatizing DOE treatment and disposal would produce essentially the same health effects, if the facilities are near or are in similar locations to those analyzed in this document.

### D.1.3 Waste Consolidation Alternatives

For each of the waste types listed in Section D.1.2, the Oak Ridge National Laboratory (ORNL) estimated the potential health effects posed by up to four general alternatives for consolidating, processing, storing, and disposing of wastes:

- No Action: Wastes are processed and/or disposed at each site using existing or approved facilities (an approved facility is one for which National Environmental Policy Act [NEPA] review has been completed, appropriate permits received, and the decision made to proceed with the facility).
- Decentralized: Wastes are processed and/or disposed at the site where they were generated.
- Regionalized: Wastes are consolidated for processing and/or disposal at regional sites.
- Centralized: Wastes are consolidated for processing and/or disposal at one or two sites.

Within each type of alternative, there were often several potentially feasible waste management options. For example, a spectrum of Regionalized Alternatives was considered for contact-handled TRUW in which

wastes are treated and stored at as many as 10 or as few as 3 sites. The rationale for selecting these alternatives is discussed in Chapter 3.

The waste processing and disposal period for the No Action Alternatives was assumed to be 20 years. For the remaining alternatives except for HLW, it was assumed that 10 years would be needed for the construction of required waste management facilities and 10 years would be required for waste processing and disposal. The risk analysis for HLW differed in that only interim storage pending final disposal was assessed because a treatment method has already been selected and is being performed at some sites.

Many DOE sites do not currently have facilities for waste management. In the alternatives evaluation, it was necessary to assume that these sites would construct the waste management facilities required under the alternative being evaluated, and that waste processing would begin after construction was completed.

The waste disposal evaluation assessed disposal only for the sites currently storing waste. It did not include federal facilities planned for waste disposal such as Yucca Mountain because these sites will be addressed in site-specific NEPA reviews (for more information on this subject, see Chapter 2).

## D.2 Evaluating the Risks Associated With Waste Management Activities

This section presents a brief introduction to the concepts and methods used to perform the human health risk analysis for the PEIS including information on the potentially exposed human populations, the means by which people could be exposed to WM Program wastes, the health effects that could result from exposure to the various wastes, and an overview of the process of estimating human health risks. In addition, this section contains a discussion of how to read and interpret the risk analysis results presented in Section D.3.

Risk analysis entails several steps including characterizing the environmental setting of the site being studied; identifying potential receptors, environmental transport pathways, and exposure routes; identifying potential human health effects to be evaluated; quantifying contaminant intakes, doses, and exposures; and calculating risks. For more detailed information on the risk analysis process used in this study, see the ORNL risk methodologies (ORNL, 1995a-c).

### D.2.1 CHARACTERIZING THE ENVIRONMENTAL SETTING

The first step in estimating risk is to collect information about the site's environmental setting including agricultural data (e.g., prevalent livestock and crops, crop yields), geographical location, climatological information (e.g., annual rainfall, storm frequency, temperature range, joint frequency distribution for wind), and land use on and around the site. The environmental setting information used in the PEIS can be found in the ORNL site description report (ORNL, 1995d).

### D.2.2 IDENTIFYING POTENTIALLY EXPOSED POPULATIONS

The next step is to identify the categories of people (called "receptors" in the analysis) who might be exposed to or affected by waste management processes. The receptor categories below were selected (1) to represent the populations that would most likely be exposed to contaminants during waste management activities or (2) as receptors potentially receiving the greatest exposure for the risk analysis. Health risks were not evaluated for persons who may drink water supplied from contaminated surface water or who derive a portion of their food supply from plants and animals that obtain water from contaminated surface water bodies.

- Offsite (general public) population: The offsite population within an 80-km (50-mi) radius of each site.
- Noninvolved workers: Onsite employees not directly involved in a site's waste handling activities.
- Maximally exposed individual (MEI) of the offsite population.
- MEI of the noninvolved worker population.
- Waste management workers: Onsite employees working in a site's waste management facilities, including both the workers directly involved in the waste management process and the construction workers who build the waste management facilities.
- Hypothetical farm family: An imaginary family of two adults and two children assumed to live 300 m (approximately 330 yd) downgradient of the center of a waste disposal facility in a period when institutional controls (fences, warning signs, etc.) no longer exist. The farm family engages in farming activities such as growing and consuming their own crops and livestock, and uses groundwater for drinking and for watering the crops and animals.
- Hypothetical intruder: An imaginary adult who drills a well directly through a waste disposal facility down to the water table (groundwater), brings the contaminated soil from within the disposal facility to the surface during drilling, and mixes the contaminated soil into the top 15 cm (5.9 in.) of surface soil of a 2,500-$m^2$ (0.6-acre) plot of land. The intruder then farms this plot and feeds him- or herself

with the crops. The intrusion scenario takes place in a period when institutional controls no longer exist.

Estimates of the offsite population and distribution within an 80-km radius of each site were obtained from the 1990 U.S. census. The population and distribution of noninvolved workers at each site were estimated based on site records, site maps, and best judgment. Because of lack of information, it was necessary at some sites to simply assume an even distribution of workers in all directions around a facility. The offsite and noninvolved worker population size and distribution for each site and the location of each site's MEIs can be found in the ORNL site description report (ORNL, 1995d).

Risks to the offsite and noninvolved worker populations were assumed to result from exposure to airborne contaminants, and were estimated only for the first 70 years after an alternative is implemented (i.e., for the lifetime of a person living during the period when treatment and storage activities take place).

The greatest risk estimates to an individual member of the offsite and noninvolved worker populations was assessed by considering the MEI in each population. In these scenarios, the MEI receives the highest total chemical intake and/or radiation dose for all exposure routes (e.g., inhalation, ingestion, direct exposure) over the person's lifetime. In considering the results of the TRUW and LLMW alternatives, note that for each *site* the MEI is one individual; however, for each *alternative* (in which the impacts from all relevant sites are considered together), the MEI is a composite of the greatest exposure to radionuclides and carcinogenic and noncarcinogenic chemicals.

The hypothetical farm family and hypothetical intruder represent two most-conservative exposure situations that occur at a time when institutional controls (fences, warning signs, land records, etc.) no longer exist, and are analyzed to determine upper-bound exposures only. The farm family is assumed to set up residence 300 m downgradient from the center of the disposal facility. The 300-m distance was chosen to ensure that the farm family's groundwater well was beyond the boundary of the disposal site (no matter what type of disposal facility is assumed for a particular site).

Risks to the hypothetical onsite farm family are evaluated for 143 consecutive 70-year lifetimes (i.e., 10,000 years) in order to determine the upper bound of long-term risks from exposure to groundwater that has been contaminated by the failure of a waste disposal facility. The maximum exposure would presumably occur in the future when the peak concentration of contaminant(s) passes the farm family's well, and might

be significant over a series of lifetimes. The 10,000-year time period was selected for the analysis in order to maintain consistency with current performance assessments and the *Guidelines for Radiological Performance Assessment of DOE Low-Level Radioactive Waste Disposal Sites* (Case and Otis, 1988). To provide some perspective on the timing of health risks predicted to result from disposal, the risk analysis identifies the 70-year lifetime (out of the 143 lifetimes evaluated) during which the highest exposures, hence, risks, are estimated to occur for the hypothetical farm family. This peak-risk lifetime is referred to in the results as the maximally exposed lifetime (MEL) of the farm family.

The intruder scenario involves chronic exposure of an individual to contaminated material brought up to the ground surface by drilling a well directly through a waste disposal facility (following guidance on intruder scenarios presented in *Intruder Scenarios for Site-Specific Low-Level Radioactive Waste Classification* [Kennedy and Peloquin, 1988]). The intruder scenario is intended to show the most conservative risk from the disposal technology itself; therefore, only the health effects from direct exposure to contaminated drilling wastes (as opposed to additional exposure to other contaminated media such as groundwater) are evaluated for this scenario. Exposure to an intruder is evaluated for one lifetime for two instances of intrusion: one at 100 years after closure of the disposal facility and one at 300 years after closure.

Worker risks are estimated both for short-term construction activities and for longer term facility operation activities. Worker activities are expected to occur over 10 to 20 years, depending on waste type and alternative, so worker risk is estimated to be a factor only during the first lifetime, or 70 years, after implementation of an alternative. The number of waste management workers involved in the various alternatives was determined as described in Section D.2.7.2.

### D.2.2.1 Populations Not Specifically Evaluated

The human health risk analysis did not explicitly include risks to sensitive subpopulations (as defined by the U.S. Environmental Protection Agency [EPA] [EPA, 1989a]) such as children, the elderly, or pregnant or nursing women; however, sensitive subpopulations were considered in the development of the toxicity and exposure values that were used in the analysis, hence, are indirectly included.

For radiological exposures, the nominal risk probability coefficients (referred to as "risk factors") used to estimate the risk of cancer and adverse genetic effects from radionuclide exposures are taken from Volume 60 of the proceedings of the International Commission on Radiological Protection (ICRP), which is referred to as *ICRP 60* (ICRP, 1990). *ICRP 60* states that "[a]lthough there are differences between the sexes and between populations of different age-specific mortality rates, these differences are not so large as to necessitate the use of different nominal probability coefficients." A small difference exists, however, between the risk factors used for workers and those used for the population as a whole. This difference arises principally because the more sensitive younger age groups and pregnant women are included in the whole population (as opposed to the worker population). With regard to the elderly, the radiological risks presented in the PEIS were calculated as the estimated risks a person would sustain over a 70-year lifespan assuming 50 years of radionuclide uptake and commitment (the concept of radionuclide commitment is explained in Section D.2.6). A person who is already elderly when a PEIS alternative is implemented would not likely be exposed for the entire 50 years. Therefore, the use of a 50-year uptake and commitment period should lead to an overestimate of the risks to the elderly. This overestimate would be more pronounced in populations containing a disproportionate number of elderly people.

The EPA slope factors and reference doses (RfDs) or reference concentrations (RfCs) used to evaluate risks from exposures to chemicals are similarly conservative. Slope factors and RfDs or RfCs are generally extrapolated from animal data and include what is termed an "uncertainty factor." This uncertainty factor is an attempt to arithmetically express how well or poorly the pharmacokinetic differences between animals and humans are understood for a particular chemical; it also accounts for the effects of the chemical on various human subpopulations. As such, these slope factors and RfDs or RfCs are considered valid for a wide range of human subpopulations. For more information on this subject, readers may wish to refer to the EPA sources for toxicity factors, the Health Effects Assessment Summary Tables (referred to as HEAST) and the on-line Integrated Risk Information System (called IRIS).

Executive Order 12898 on environmental justice mandates adding the dimension of minority and low-income populations to research, data collection, and analysis to the extent practicable and appropriate. Certain Native American and minority or low-income populations might consume larger quantities of locally grown produce or fish from local water sources than the population as a whole; this situation might result in higher risks to these particular people.

DOE has not evaluated the human health risk to subpopulations that may derive a substantial portion of their food supply from native plants and animals that live near the DOE sites. The results of such a complex analysis would likely vary widely both within and among sites, depending on the assumptions used for parameters such as locations of waste management facilities on the sites, routes of exposure, and dietary habits. Thus, the results would not help to clarify programmatic decisions. The risk to human health from ingesting native plants and animals cannot be fully analyzed with confidence until the locations of facilities on the sites are known, the routes of exposure are explicitly defined, and the dietary habits of affected subpopulations are quantified. Therefore, analysis of health effects from subsistence consumption of fish, wildlife, and native plant species is not included in the WM PEIS but may be considered in subsequent sitewide or project-specific NEPA documents if the appropriate information is available.

### D.2.3 Identifying Environmental Transport Pathways

The next step in the risk analysis process is to identify the pathways between the sources of contamination and the individuals or populations at risk. These pathways are the actual physical routes along which the contaminants would travel from the source to the exposed individual or population.

Waste management workers working at waste management facilities can come into direct contact with wastes and/or waste containers and with intrafacility airborne contamination during routine treatment, storage, and disposal operations, and during accidents. The remaining receptors become exposed only if contaminants are released from the waste management facility to environmental media such as air or groundwater. For the purposes of the PEIS, it is assumed that contaminants are released (1) to the air during waste treatment operations and accidents, (2) to the groundwater at some point after wastes have been disposed of in engineered disposal facilities, and (3) to the surrounding soil upon intrusion into disposal facilities following institutional control. During treatment operations and accidents, area winds carry released contaminants from the treatment facility toward the offsite and noninvolved worker populations. These airborne contaminants can be inhaled as well as deposited on plants and soil. Wind also transports the contaminated soil that the intruder brings to the surface during drilling and mixes into his/her farm plot. In the waste disposal scenarios, it is assumed that contaminants leach from the facility to the groundwater and are transported downgradient toward the hypothetical farm family's drinking water well.

### D.2.3.1 Transport Pathways Not Evaluated

DOE has not evaluated the human health risk to persons who may drink water supplied from contaminated surface water or who derive a portion of their food supply from plants and animals that obtain water from surface water bodies. This is a complex analysis that cannot be performed with confidence until the locations of the facilities on the sites are known and the routes of exposure explicitly defined. Therefore, analysis of health effects from the surface water pathway is not included in the WM PEIS but may be considered in subsequent sitewide or project-specific NEPA documents. A limited analysis was performed to show the potential health effects from the deposition of airborne contaminants on surface water bodies.

**Deposition of Radionuclides Onto Surface Water with Subsequent Ingestion**. The deposition of contaminants by an airborne plume on an exposed body of water was eliminated as a pathway from detailed quantitative analysis. Preliminary tests were performed to determine the order-of-magnitude impacts of this secondary exposure pathway. These tests, which involved varying rates of flow of surface water, widths of surface water bodies, and distances from the atmospheric source to the receptor, demonstrated that the contribution of this secondary pathway to the final dose was at least 3 orders of magnitude smaller than the dose resulting from inhalation of the plume. Tests were performed for a hypothetical unit release and atmospheric deposition of several representative radionuclides using parameters associated with the Columbia River near Hanford (Washington) and the Clinch River near ORNL (Tennessee). The Columbia has an average width of 457.2 m, an average depth of 6.1 m, and an average flow speed of 1.2 m/s. The Clinch River has an average width of 124.3 m, an average depth of 9.1 m, and an average flow speed of 0.1 m/s. For the test, the atmospheric source was located at three different distances from both rivers: 10 m, 300 m, and 16.1 km. The receptor was located at the river and drank 1 L (0.9 qt) of contaminated water per day. The cancer incidence risk from inhalation of the plume is compared with the cancer incidence risk from ingestion of the contaminated water. Table D.2–1 summarizes the results for uranium–238.

**Deposition of Chemicals Onto Surface Water With Subsequent Ingestion**. Tests were performed for exposure to unit releases of chemicals for some of the same scenarios outlined above. Benzene and 1,1,1-trichloroethane were chosen because both are in the PEIS source terms (Table D.2–2). Benzene is a carcinogen for inhalation and ingestion, and 1,1,1-trichloroethane is a noncarcinogen for inhalation and ingestion. Chemicals that exhibit carcinogenicity for ingestion but not for inhalation (or vice versa) were not examined because an accurate comparison could not be made.

***Table D.2–1. Preliminary Surface Water Analysis Results for Radionuclides***

| Contaminant: Uranium–238 | | | | |
|---|---|---|---|---|
| **River** | **Distance (m)** | **Ingestion Cancer Incidence Risk** | **Inhalation Cancer Incidence Risk** | **Approximate Difference[a]** |
| Columbia | 10 | 2.4E–11 | 4.9E–01 | 10 orders of magnitude |
| | 300 | 5.3E–13 | 3.6E–04 | 9 orders of magnitude |
| | 16,100 | 7.7E–15 | 9.5E–08 | 7 orders of magnitude |
| Clinch | 10 | 3.4E–12 | 3.6E–04 | 8 orders of magnitude |
| | 300 | 7.7E–11 | 2.4E–01 | 10 orders of magnitude |
| | 16,100 | 1.0E–13 | 1.9E–07 | 6 orders of magnitude |

[a] Difference (in orders of magnitude) between cancer incidence risks for ingestion versus inhalation.

***Table D.2–2. Preliminary Surface Water Analysis Results for Chemicals***

| Columbia River at 300 m | | | | | |
|---|---|---|---|---|---|
| **Contaminant** | **Ingestion Hazard Quotient** | **Inhalation Hazard Quotient** | **Ingestion Cancer Incidence Risk** | **Inhalation Cancer Incidence Risk** | **Approximate Difference[a]** |
| Benzene | -- | -- | 7.5E–19 | 8.7E–10 | 9 orders of magnitude |
| 1,1,1-Trichloroethane | 1.4E–14 | 7.8E–06 | -- | -- | 8 orders of magnitude |

[a] Difference (in orders of magnitude) between hazard indices and cancer incidence risks for ingestion versus inhalation.

### D.2.4 Identifying Likely Exposure Routes for Populations and Individuals

The following sections describe the exposure routes by which the various receptors may come into contact with radiological and chemical contaminants. These exposure routes are illustrated in Figures D.2–1 through D.2–4.

#### D.2.4.1 Offsite and Noninvolved Worker Population Exposure Routes

It was assumed that the offsite population could be exposed to radionuclides, carcinogenic chemicals, and noncarcinogenic toxic chemicals by coming into contact with contaminated air. Airborne contaminants can be inhaled, taken up by agricultural animals and plants and subsequently ingested, or can cause direct (external) exposure via immersion in a plume of contaminated air or exposure to contaminated soil. Noninvolved workers were assumed to be exposed only to atmospheric releases, because institutional controls should ensure that this population is not exposed to contaminated groundwater or surface water through drinking or showering.

The offsite and noninvolved worker populations were evaluated for dermal exposure to tritium derived from tritiated water in the atmosphere. Both absorption through the skin and the lungs were taken into account; this combined rate of absorption was assumed to be 150% of the inhalation intake rate alone (Napier et al., 1988).

#### D.2.4.2 Hypothetical Farm Family Exposure Routes

The risks to the hypothetical farm family were analyzed only for the waste types that will be disposed of in DOE facilities (e.g., LLW and LLMW). It was assumed that the farm family could be exposed directly and indirectly to groundwater contaminated by a release from the disposal facility. Shallow land disposal facilities were assumed to allow immediate releases; tumulus and below-ground vault disposal facilities were assumed to fail and allow release in 300 and 750 years, respectively. The exposure routes evaluated for the farm family include ingestion of contaminated groundwater and ingestion of crops and animals contaminated by exposure to groundwater.

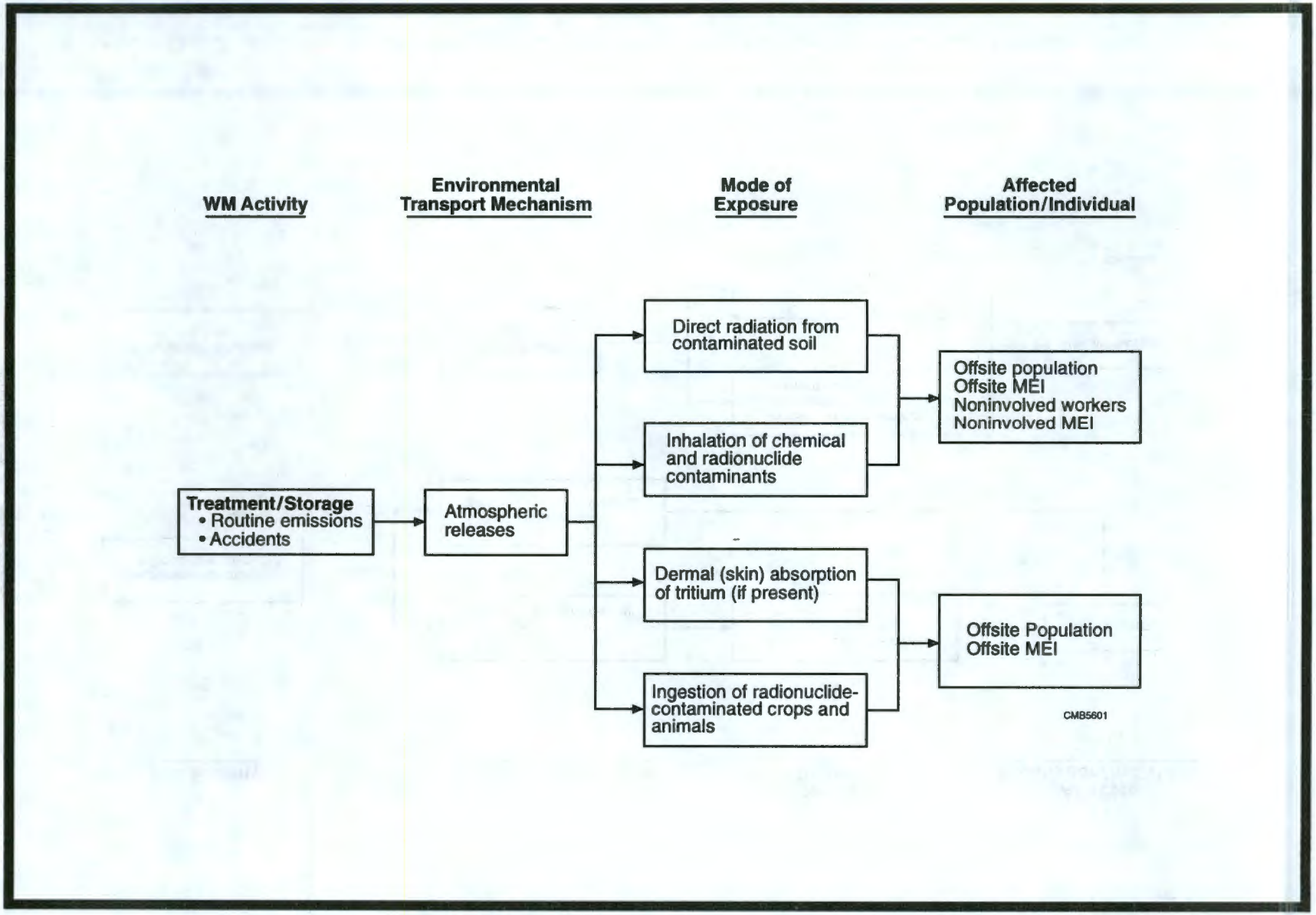


*Figure D.2–1. Exposure Routes for the Offsite and Noninvolved Worker Populations for Treatment and Storage Activities*

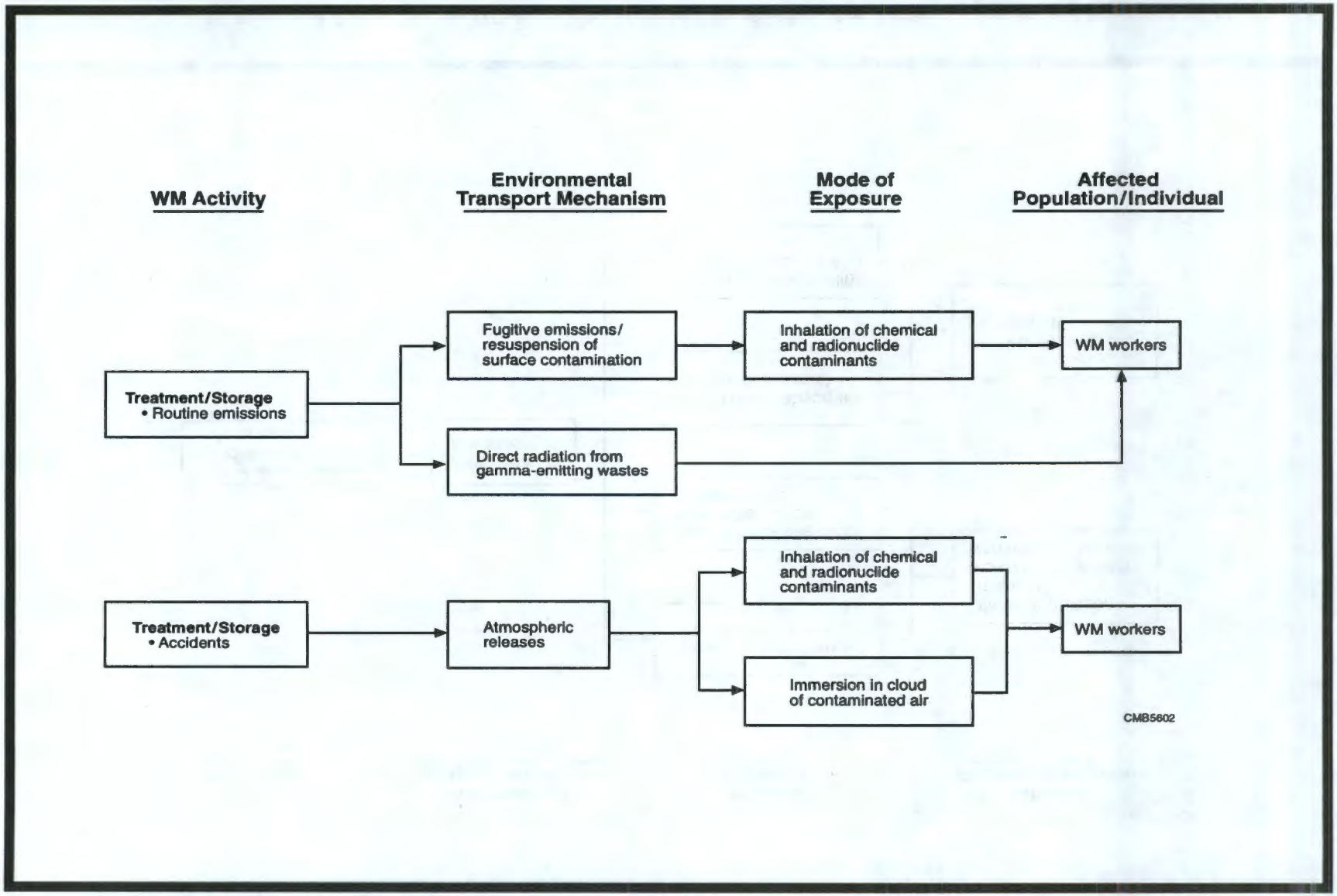


*Figure D.2–2. Exposure Routes for Waste Management Workers for Routine Operations and Accidents During Waste Treatment and Storage*

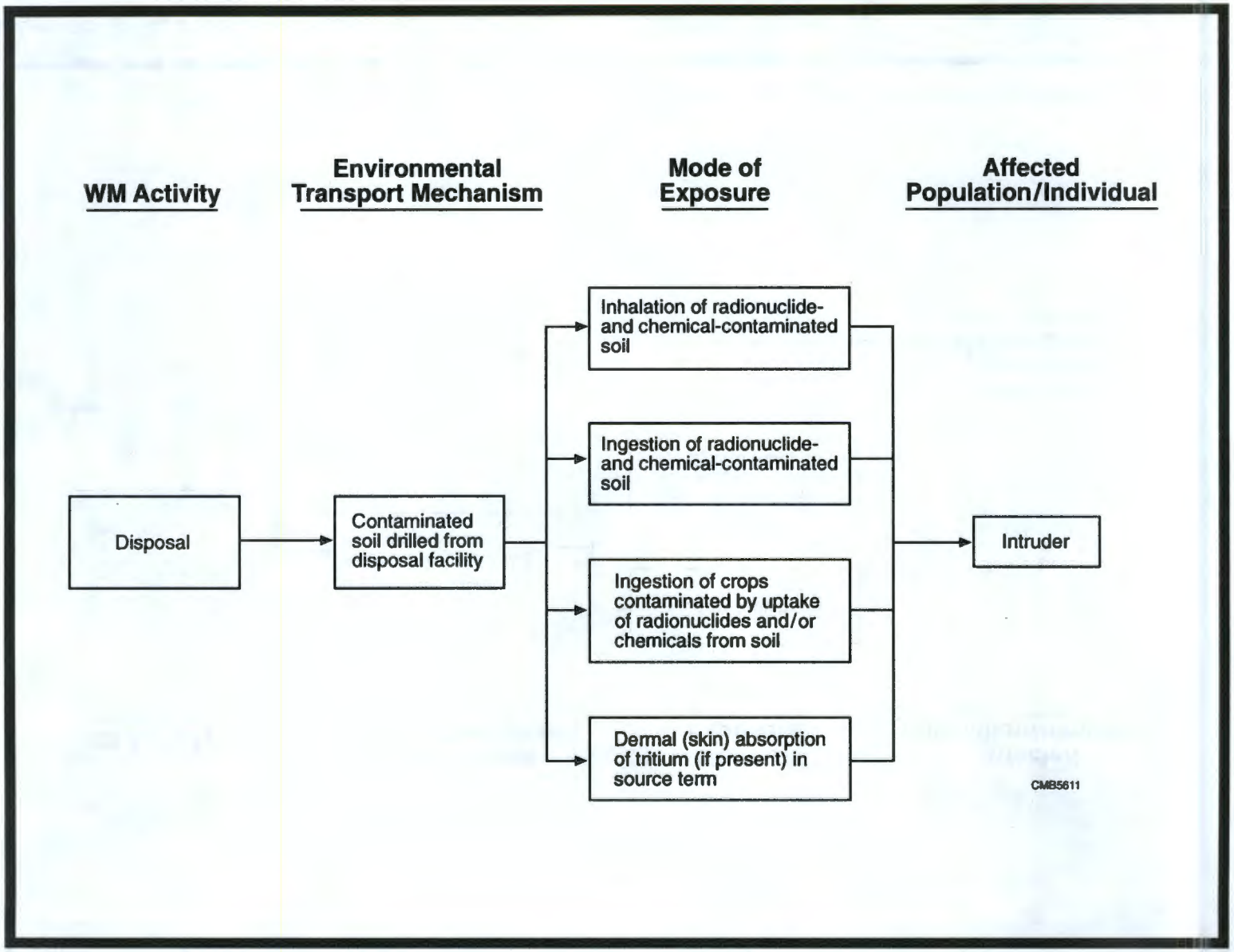


*Figure D.2–3. Exposure Routes for the Intruder for Disposal Activities*

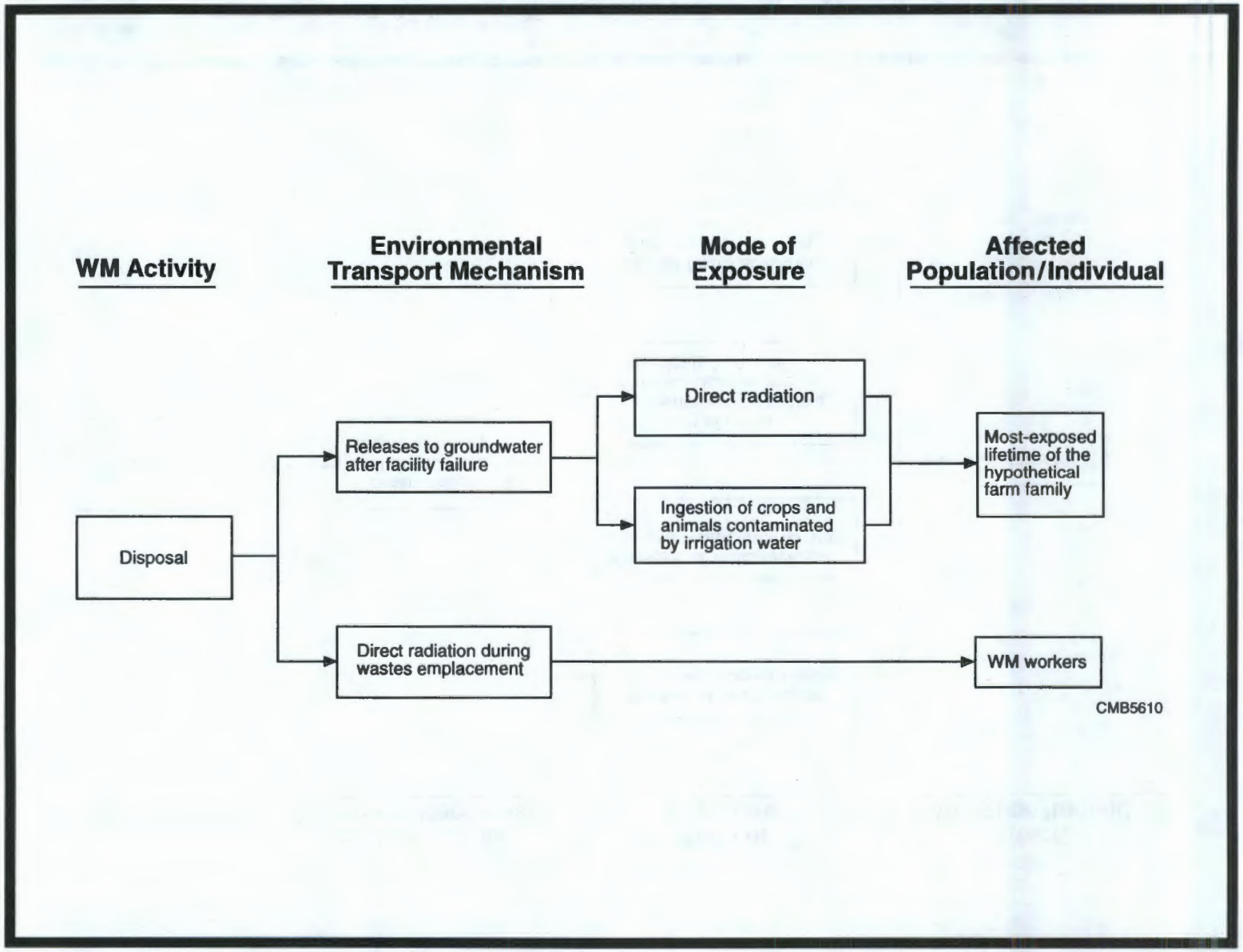


*Figure D.2–4. Exposure Routes for the Farm Family and Waste Management Workers for Disposal Activities*

### D.2.4.3 Hypothetical Intruder Exposure Routes

Exposure of the intruder was assessed only for LLW and LLMW, the waste types that will be disposed of in DOE facilities. The exposure routes evaluated for the intruder involve exposure to soil contaminated with radionuclides for LLW and with radionuclides and hazardous chemicals for LLMW. These exposure routes are direct radiation from the soil, ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil (for radionuclides); and ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil (for chemicals).

### D.2.4.4 Worker Exposure Routes

To provide an overview of the program-level health impacts from waste treatment, storage, and disposal activities, the risks to waste management workers include the risks to workers building waste management facilities. Workers directly involved in treatment, storage, and disposal were assumed to be exposed to contaminated air in work areas resulting from fugitive treatment emissions and resuspended surface contamination on waste containers, to receive external exposure from radioactive wastes, and to be at risk of death or injury from industrial-type physical hazards. The worker exposures associated with placing wastes into disposal facilities were assessed separately from treatment risks. Construction workers were assumed to be exposed only to construction-related physical hazards, not to radiological and chemical wastes. The construction and operational risk factors used in this risk analysis are based on current statistics from the U.S. Bureau of Labor Statistics and the National Safety Council, as discussed in the PEIS unit risk methodology (ORNL, 1995c). At sites where no construction was assumed, these risks were not estimated.

## D.2.5 Identifying the Human Health Effects to Be Evaluated

The PEIS focuses on certain human health impacts as one of the bases for comparing the various waste management alternatives. In this risk evaluation, it was assumed that health effects, which might range from mild clinical symptoms of chemical exposure to bodily injury, illness, or death, could result from exposure to radionuclides, carcinogenic chemicals, and noncarcinogenic toxic chemicals as a result of both routine waste management operations and potential accidents. In addition to exposure-related health problems, waste management workers were assumed to be at risk of on-the-job injuries or deaths from physical trauma

(falls, crushing, electrocution, etc.). The following health effects, called "endpoints" in the analysis, were evaluated:

- Cancer incidence from radionuclide and chemical exposures
- Cancer fatalities from radionuclide exposures only
- Adverse genetic effects caused by exposure to radionuclides
- Hazard index for nonworkers (an indicator of the likelihood of noncancer toxicity caused by continuous exposure to nonradioactive waste components)
- Exposure index for workers (an indicator of the likelihood of noncancer toxicity caused by work-day exposure to nonradioactive waste components)
- Waste management worker fatalities and injuries associated with the construction and operation of waste management facilities

In addition, in the accident scenarios, an "immediately-dangerous-to-life-and-health (IDLH) index" was calculated for workers as an indicator of the likelihood that contaminant levels might impair escape or be immediately dangerous to life and health.

For the purposes of this evaluation, the concepts of cancer incidence and cancer fatality refer to what are termed "excess cancers," i.e., cancers that would not otherwise have occurred. These terms encompass all types of cancer and any occurrence(s) of cancer over the 70-year lifetime of an individual.

**Radiation-Related Health Effects.** It was assumed that exposures to radiation can result in cancer incidence, cancer fatality, and adverse genetic effects. Adverse genetic effects include gene mutations (alterations in the elementary units of heredity, the genes) and gross chromosomal aberrations (changes in the structure or number of chromosomes). Because exposure to contaminants in and from DOE sites might occur over many generations, concern exists that the cumulative genetic damage carried benignly across generations might, at some point, produce disease that is not accounted for in the basic cancer risk calculations.

The frequency with which these three health effects occur was assumed to be directly proportional to the amount of radiation absorbed by the receptor (see the discussions on "effective dose equivalent" and dose "commitment" in Section D.2.6). Moreover, these impacts were assumed to occur in a fixed ratio to one another. For example, for all receptors except waste management workers, the ratio of cancer incidence

to cancer fatality to genetic effects was taken to be 17:5:1 (see Section D.2.8.1 for a more detailed discussion of these assumptions).

**Chemical-Related Health Effects.** It was assumed that exposure to hazardous (nonradioactive) chemicals can cause cancer and/or a spectrum of toxic effects ranging from mild headaches or nasal irritation to more serious impacts such as organ (e.g., liver, kidney) toxicity, neurotoxicity, immunotoxicity, developmental toxicity, reproductive toxicity, and genetic toxicity.

The risk of cancer fatality was calculated for radionuclides but not for chemical carcinogens; this is discussed in more detail in Section D.2.6.3.

### D.2.5.1 Factors Excluded From the Analysis

The risks from enhanced or diminished toxicity from interactions among components of a contaminant mixture (termed "synergy" and "antagonism," respectively), or the effects of multiple chemical forms of the same atom ("speciation") or combination of atoms ("complexing") were not evaluated because not enough information exists on these effects. If synergism or antagonism is occurring at a particular site, the risks there will be accordingly under- or overestimated. Similarly, since complexing and speciation can affect a contaminant's physicochemical and health-related properties including its toxicity, carcinogenicity, reactivity, and water solubility (hence, transportability), the lack of toxicity information on waste complexing and speciation may introduce some additional uncertainty to the risk analysis.

## D.2.6 Quantifying Contaminant Intakes, Doses, and Exposures

This section presents a brief overview of how chemical and radiological exposures are measured. For more information, refer to the EPA risk assessment guidelines (EPA, 1989a) and the ORNL risk methodologies (ORNL, 1995a,b).

### D.2.6.1 Quantifying Chemical Intake and Exposure

Chemical hazards are generally quantified by an individual's intake of a chemical. Intake is expressed in milligrams of contaminant ingested, inhaled, or absorbed per kilogram of body weight per day. When evaluating health effects from chemical exposure, intake values for noncarcinogenic chemicals are compared to EPA RfDs or RfCs as published in HEAST (EPA, 1992b) and IRIS (EPA, 1991c) (for all receptors except waste management workers), and intake values for chemical carcinogens are multiplied by EPA cancer slope factors (EPA, 1991c, 1992b) (for all receptors). For workers, American Conference of Government Industrial Hygienists' (ACGIH) time-weighted average threshold limit values (TWA–TLVs, or more simply, TLVs) are used rather than RfDs or RfCs, since TLVs are based on workday exposure concentrations (ACGIH, 1992).

There are many uncertainties inherent in the process of formulating RfDs and cancer slope factors. For example, a margin of safety is incorporated into these values (i.e., these values tend to overestimate the risk of the toxicant to some degree to help ensure that human health is protected). In addition, uncertainties are introduced when the findings of dose-response research performed on animals are applied to humans; findings of studies performed at high exposure levels are extrapolated to low exposure levels; results concerning acute exposures are extended to chronic exposures; and findings from occupational conditions are used to characterize toxicity in nonoccupational or environmental conditions.

The magnitude of these uncertainties is not well known; estimates from different studies vary depending upon factors such as the number of studies performed for a particular substance and the receptors and scenarios for which the substance was investigated.

### D.2.6.2 Quantifying Radiological Dose and Exposure

A variety of units are used to indicate the amount, intensity, and potential health effects of radiation. The "curie" (abbreviated Ci) is a measure of the amount of radioactive decay occurring in a sample of radioactive material, and is defined as 37 billion disintegrations (individual radioactive decay events) per second. The rate of decay of 1 g of radium is the basis for this unit of measure. Amounts of radionuclides are commonly measured in curies or fractions of curies such as the picocurie (pCi), which is a trillionth of a curie. Emission rates are typically measured in picocuries per year (pCi/yr), and concentrations in units such as picocuries per cubic meter (pCi/m$^3$) or picocuries per gram (pCi/g).

The same dose (absorbed by the human body) of different types of radiation (e.g., alpha, beta, gamma) can produce different health risk outcomes and different effects on living cells. To standardize for these effects, a unit of radiation measure called a "rem" is used as a way of measuring the biological effects of a given dose of any type of radiation. The rem has built-in factors that weight the dose according to each type of radiation's capacity for causing biological damage (this capacity is called the "biological effectiveness" of the radiation). Hence, 1 rem of one type of radiation (for example, gamma radiation) is presumed to have the same biological effects on a given type of tissue as 1 rem of any other type of radiation (say, beta radiation). This unit of measure allows comparison of the biological effects (on a given type tissue) of radionuclides that emit different types of radiation. A millirem (mrem) is one-thousandth of a rem. See the ORNL worker risk methodology (ORNL, 1995b) for a more detailed description of the different types of radiation.

The various organs of the body have different susceptibilities to harm from radiation; for example, the gonads tend to be more sensitive to radiation damage than the cornea of the eye. The unit of measure that takes these different susceptibilities into account to provide a broad indicator of the total effective radiation dose is called an "effective dose equivalent" (or "EDE"). It is obtained by multiplying the dose (or "dose equivalent") in rems in each major organ or tissue by a weighting factor associated with the risk susceptibility of the tissue or organ, then summing the totals. This unit of measure allows comparison of the general adverse consequences to people who are exposed to radiation, regardless of the different susceptibilities of individual types of tissue in different organs to such exposure. For a more detailed discussion of organic and tissue weighting factors, see the ORNL worker risk methodology (ORNL, 1995b).

Three types of radiation doses are calculated in the PEIS: an external dose, an internal dose, and a combined external and internal dose (or total dose). External doses are from sources located outside the body such as a sealed radioactive container or contaminated air, water, or soil. Internal doses arise from sources that have entered the body, usually from eating or drinking contaminated substances or breathing contaminated air.

### D.2.6.3 Comparing Radionuclide Exposures to Chemical Exposures

Radionuclide and chemical exposures are, for the most part, very different from one another. A chemical contaminant may be released to groundwater or dispersed into the air, whereupon it is deposited on the ground, vegetables or other crops, or other surfaces. A person becomes exposed by inhaling the contaminant, drinking contaminated water, eating contaminated vegetables, etc. A number of chemicals, such as mercury, lead, and PCBs, bind to or "bioaccumulate" in various body tissues such as bone and fat and may continue to cause toxic effects long after initial exposure. However, quite often, a chemical that has entered the body exerts its toxic or carcinogenic effect over a relatively short period of time and is excreted or otherwise eliminated from the exposed person's body. (The time required for a living organism to eliminate half the amount of an absorbed or ingested chemical substance by natural processes is termed the "biological half-life" of that substance.)

There seems to be an exposure *threshold* for noncancer effects caused by chemicals that do not bioaccumulate. Above this threshold exposure level, these chemicals begin to exert adverse effects; below the threshold, their effects seem to be negligible. A person can be exposed many times to less than the exposure threshold of chemicals that do not bioaccumulate and show no cumulative adverse noncancer effects.

Based on the characteristics of the contaminants of concern in the WM Program waste types, it was assumed in this risk analysis that chemical contaminants of concern do not significantly bioaccumulate. Accordingly, the exposure time for toxic chemicals was assumed to equal the release time. The release time was assumed to be equal to the total processing period for the waste type in question (e.g., 10 or 20 years). While this assumption may be somewhat conservative, it is applied across all sites; hence, the *relative* ranking of sites by risk will likely remain the same.

People are exposed to radionuclides by the same mechanisms as they are to chemicals. However, radionuclides may be present in forms such as simple salts that, when ingested, can be incorporated into body tissues (such as bone) more readily than many hazardous chemicals. Radionuclides may also adhere to particles that, once inhaled, are too small for the lungs to expel. In these circumstances, a radionuclide will stay in the body and continue to deliver a radiation dose long after the exposed person has stopped ingesting or inhaling the radionuclide. (The persistence time of a radionuclide in a living organism is measured in terms of the radionuclide's "effective half-life." This is the period of time required for the

amount of radionuclide in an organism to diminish 50% from the combined action of radioactive decay and biological elimination.)

Based on the radionuclides found in the WM waste types and ICRP guidance (ICRP, 1977; 1990), it was assumed that most ingested or inhaled radionuclides remain in the body and continue to expose the person for the rest of his or her life (i.e., the internal dose continues to accumulate). In risk analysis, this continuing, cumulative internal exposure period is referred to as the "commitment period." A commitment period of 50 years was chosen for this study (ICRP, 1990). This time period reflects the average person's working lifetime beginning at age 18, and is a standard time period used in risk assessments. Accordingly, in this study, the risks from radionuclide exposure are calculated not just for the waste treatment time span (10 or 20 years, according to waste type) but as though the internal exposure period persists for a total of 50 years (this does not apply to external exposure to radiation). Therefore, the total EDE deposited in the body over the 50 years after intake of a radionuclide, called the "committed EDE," is used in the PEIS risk calculations.

Because we do not have a clear understanding of the biological processes by which chemicals and radiation cause cancer, a conservative approach (and the one adopted in the PEIS) is to assume that there is *no minimum or threshold value for exposures to carcinogens*. This means that any exposure to a carcinogen increases the lifetime risk of cancer. Consequently, it is assumed that the risk of cancer accumulates with repeated exposures to carcinogens and that the risk of cancer from multiple exposures to multiple sources is additive.

The risk of cancer fatality was calculated for radionuclides but not for chemical carcinogens. This is because research and epidemiological studies have provided enough information to develop risk factors for both cancer incidence and fatality caused by radionuclides; however, there is not yet enough information to develop risk factors for cancer deaths resulting from chemical exposures. These differences between the amounts of information available about cancers associated with chemical and radionuclide exposures have another implication: The risk of cancer incidence from exposure to hazardous chemicals is not, strictly speaking, directly comparable to the risk of cancer incidence from exposure to radionuclides (this becomes an issue only in the risk analyses for TRUW and LLMW, which contain both radionuclides and hazardous constituents). Readers should bear this in mind when assessing the risk analysis results.

### D.2.7 Calculating Exposures for the PEIS Receptors

This section presents a brief introduction to the methods used to model the fate and transport of chemical and radiological contaminants between their initial release and the point at which the various receptors are exposed, and to calculate the unit chemical intakes and radiological doses the receptors receive.

For every potential contaminant in these studies, it was assumed that one unit amount of contaminant is released to various environmental media (e.g., air, soil, or groundwater); or, for worker exposures to radionuclides, is available to cause direct exposure. This unit is 1 Ci for radionuclides and 1 g for chemicals. Appropriate fate and transport models and dose assessment models were then used to estimate the exposures the various receptors sustain from this unit of contaminant. These models use information about the physical and chemical properties of the contaminants and the specific environmental setting in which the contaminants were released to calculate the direction in which the contaminants move; the rate at which they move into different environmental media (for example, air, soil, water); their dilution, dispersion, and degradation or decay; and their movement via the food chain. The models described below are discussed further in Section D.5 and in supporting ORNL technical reports (ORNL, 1995a-c).

#### D.2.7.1 Calculating Exposures to the Offsite and Noninvolved Populations, Hypothetical Farm Family, and Hypothetical Intruder

**Regulatory Considerations for Public Receptors**. While there are regulatory standards governing the maximum permissible radionuclide and chemical exposures to members of the public (i.e., to all receptors other than waste management workers), the doses to these receptors were not limited in this analysis for two reasons. First, a waste management facility is a relatively controlled environment so worker exposures are somewhat more easily monitored than exposures to the public. Second, leaving the predicted exposures to the offsite and noninvolved worker populations unmodified enables the reader to make a better assessment of the maximum risks among the various PEIS alternatives. (Applicable environmental requirements would be taken into account in the implementation of a selected alternative).

**Estimating Doses From Contaminated Groundwater**. For the groundwater pathway, the computer models DUST (Disposal Unit Source Term) (Sullivan, 1992), MEPAS (Multimedia Environmental Pollutant Assessment System) (Droppo et al., 1989), and DITTY (Dose in Ten Thousand Years) (derived from the GENII model) are used to simulate environmental transport of contaminants from the source (waste disposal

location) to groundwater to potential receptors. Contaminant-specific unit rate of transfer (flux) rates out of the engineered disposal facility are generated by DUST and are used by MEPAS to simulate the transport of contaminants through the vadose zone (the area above the permanent groundwater level) and into the groundwater. The MEPAS model then predicts the environmental concentration of contaminants at various receptor locations as a function of time. For radionuclides, the 70-year average concentrations from MEPAS are used by DITTY to predict the dose to receptors for each radionuclide. For hazardous chemicals, the 70-year average concentrations are multiplied by standard intake values for water and food to arrive at a contaminant-specific intake, which is multiplied by the size of the drinking water population to give the total contaminant dose for each 70-year period.

Radioactive decay and ingrowth of daughter products are taken into account at several points during the estimation of dose from the groundwater pathway. Radioactive decay that occurs prior to the disposal facility breach is calculated, and the contaminant inventory is modified accordingly. Decay that occurs after the facility breach and during transport to the vadose zone is accounted for prior to the transfer of flux rates to MEPAS. The MEPAS model then accounts for radioactive decay and ingrowth involved in transport through the vadose and saturated zones. All doses from daughter products are attributed to the parent radionuclide in the analysis results.

**Estimating Radionuclide Doses From the Atmosphere**. For atmospheric transport of radionuclides, doses are estimated by a program called GENII (Generation II of the Hanford Environmental Radiation Dosimetry Software System) (Napier et al., 1988 ). GENII contains algorithms, data, and methods for calculating radiological doses to various organs and tissues and for calculating EDEs based on ICRP guidance (ICRP, 1977, 1979). To create unit doses for the atmospheric release of radionuclides, GENII is run using an emission rate of 1 Ci per year for each radionuclide in the GENII library. The GENII program then uses the modeled atmospheric concentrations to predict the unit dose to potential receptors. A separate unit dose is generated for both an acute (i.e., 24-h) release period and a one-year release period. The unit dose calculated for acute releases is used to evaluate the accidental release scenarios. The one-year unit dose is used to project cumulative doses associated with chronic release scenarios. This is accomplished using radionuclide-specific cumulative dose conversion equations, which calculate the cumulative EDE based on the number of years of release. As previously noted, when calculating the cumulative EDE, radioactivity is assumed to be continually deposited in the body for 50 years after exposure occurs. GENII also accounts for radioactive decay and ingrowth of daughter products; all doses from daughter products are attributed to the parent in the analysis results.

**Estimating Chemical Intakes From the Atmosphere**. For chemicals, ISC2 dispersion models (Industrial Source Complex Dispersion Models, Version 2) (EPA, 1992a) are used to estimate exposures to contaminants. To create site-specific unit intakes for the atmospheric release of chemicals, ISC2 is run using an emission rate of 1 g/s with site-specific information for wind distribution. The ISC2 model predicts atmospheric concentrations based on this emission rate for each block in a circular grid comprising 16 directional sectors (e.g., north, north-northeast, northeast, east-northeast, etc.) at 10 radial distances out to 80 km (50 mi) from the point of release, yielding a distribution of unit atmospheric concentrations. The highest concentration in a block with actual population is used to generate the MEI's intake, while the population-weighted average concentration is used to generate the population intake. Recall that, unlike radionuclides, there is no commitment period for chemical exposures. To generate the unit intakes for chemicals, the unit air concentration predicted by ISC2 is converted to a unit intake using standard exposure parameters developed by the EPA, such as how much air an average-sized adult breathes per day (EPA, 1991a).

**Estimating Doses and Intakes From Contaminated Soil for the Intruder Scenario**. This estimate is based on the inventory of contaminants in the disposal facility. Contaminant concentrations in soil are derived for the intruder by (1) calculating the volume of the cylinder of soil removed from the waste facility during drilling; (2) multiplying the inventory in the disposal facility by the ratio of the well volume to the facility volume to derive the amount of contaminant removed by drilling; and (3) calculating the final concentration of contaminant in the 2,500-$m^2$ farm plot after the contaminated well-drilling soil is mixed into the top 15 cm of plot soil.

The exposure pathways evaluated for radionuclides are direct radiation from the soil, ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil. The exposure pathways for chemicals are ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil. The GENII computer model is used to calculate the 50-year cumulative EDE for radionuclide exposures. This dose is multiplied by the appropriate risk factors to calculate the resulting potential cancer fatalities, cancer incidence, and genetic effects. Radioactive decay and ingrowth of daughter products are accounted for in both intruder scenarios. An enhanced version of the PRESTO computer model (Fields et al., 1986; Fields and Mellescue, in preparation) is used to calculate the cancer incidence for carcinogenic chemicals and the hazard index for noncarcinogenic chemicals.

### D.2.7.2 Calculating Exposures to Waste Management Workers

**Characterizing Waste Management Facilities and Treatment Processes**. Estimating worker exposures calls for characterizing the various waste management facilities and treatment processes used in each alternative. To make comparative analysis possible, these characterizations are based on the conceptual designs of "generic" waste management facilities developed by EG&G Idaho, Inc., for estimating the costs associated with the various PEIS alternatives, and on consistent assumptions about worker activities and worker protection (EG&G, 1992). Each individual process or step of treating, storing, and disposing of a waste (such as retrieving waste from current storage, receiving and inspection, shredding and compaction, incineration, solidification, interim storage, packaging, shallow land burial, and below-ground vault disposal) is identified and analyzed separately for risk as a "module." Each module serves conceptually as a self-contained "box" within which worker exposures may occur; each can contain several submodules or worker activities (see ORNL, 1995b).

Modules can be arranged to form "treatment trains" that contain all the processes required to treat, store, and dispose of a specific type of waste. A treatment train for solid LLW, for instance, might consist of size reduction (shredding), compaction, packaging, and shallow land burial. These generic modules are interchangeable and can be used as needed to formulate the treatment trains for all the different waste types in the analysis (for example, the incineration module is used in several of the treatment trains for HW, LLW, LLMW, and TRUW; and the compaction module is used in many of the treatment trains for LLW, LLMW, and TRUW).

**Estimating Staffing Requirements**. Once the various types of waste management facilities have been characterized, staffing requirements are then estimated. To make it possible to compare estimated worker exposures to regulatory criteria, staffing was expressed as the number of "full-time equivalents" (FTEs). An FTE was assumed to be commensurate to one individual working full-time in a waste management facility. In reality, one FTE could represent several individuals who are not exposed full-time to waste management activities, but whose *cumulative* work time totals one FTE. Because the risk of exposure could be shared by more than one worker working less than full-time in a waste management facility, risks to actual individual workers might be overestimated. When interpreting the risk analysis results, readers may find it useful to think of an FTE as a hypothetical worker or "worker equivalent." Note that radiation doses to workers are expressed in FTE-rem instead of person-rem.

The staffing requirements for facilities of various sizes were estimated using equations developed through linear regression analysis. These equations, which predict the number of FTEs needed according to facility capacity, were based on data points provided by EG&G Idaho, Inc. It was assumed that the facilities operate at 70% availability (i.e., they are not operating the other 30% of the time). Workers are assumed to be exposed by treatment or handling processes 5.6 hours/day, 240 days/year, totaling 1,344 hours/year (EG&G, 1992).

**Regulatory Considerations for Waste Management Workers.** Regulatory requirements have been established to limit exposures of workers to radionuclides and hazardous chemicals. These requirements are generally considered to be conservative to ensure safe conditions for workers. Code of Federal Regulations, Title 10, Chapter 835 (abbreviated "10 CFR 835") and DOE Order 5480.11 specify that the maximum allowable worker exposure to radionuclides is 5 rem/year. However, DOE installations institute their own additional radioactive waste operations procedures and administrative exposure limits for workers. DOE facilities adhere to the principle that radiological exposures should be kept "as low as reasonably achievable" (the "ALARA" principle). Guidance documents such as the Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, Standard Operating Safety Guides, and Field Standard Operating Procedures provide information oriented toward reducing exposures at hazardous waste sites. One of the primary assumptions of the worker risk analysis is that waste management worker exposures do not routinely exceed occupational exposure limits. This assumption is based on historical occupational exposure data showing that workers involved in routine operations are generally exposed to levels less than these limits. According to the DOE Radiological Control Manual (DOE, 1994), the DOE Administrative Control Level per person is 2,000 mrem. However, the Manual also states that "an annual facility Administrative Control Level of 500 mrem or less should be challenging and achievable. An annual facility Administrative Control Level above 1,500 mrem is in most cases not sufficiently challenging to meet the goals of this Manual." Therefore, for the worker risk analysis, the radiation exposure guideline of 1,000 mrem/year (1 rem/year) is assumed to be the upper bound of worker exposure to radiation.

Estimated air concentrations are also compared to occupational exposure criteria such as TLVs for chemicals and EPA derived air concentrations for radionuclides to evaluate worker exposure conditions. The methodology used to estimate worker risks assumes the use of good work practices under normal conditions. If a TLV is not available for a particular chemical, estimated air concentrations of that chemical may be compared instead to 10% of the IDLH concentration, as established by the National Institute for Occupational Safety and Health (1992). The IDLH level is defined as the maximum air concentration to

which an individual without a respirator can be exposed for 30 min without suffering escape-impairing or irreversible health effects; 10% of that level is considered the boundary between negligible and reversible health effects for a 30-min exposure (ORNL, 1995b).

**Estimating Doses From Indoor Air**. For indoor scenarios in which individuals work inside treatment, storage, and disposal facilities, air concentrations are estimated using a room model (Jayjock, 1988). Contaminant releases are assumed to be distributed evenly throughout the entire volume of the room where treatment takes place. Intakes or doses from inhalation are estimated for each module, contaminant, and worker classification. For the worker risk evaluation, 10% of the stack emissions are assumed to escape from the module into the room (EPA, 1989b). Stack emission rates from treatment, storage, and disposal facilities are provided by ANL. Dose conversion factors used to calculate committed EDEs for inhalation of radionuclides are obtained from the EPA (EPA, 1988).

**Estimating Doses From External Radiation**. Doses received by treatment, storage, and disposal workers from exposure to radiation from sources external to the body (not inhaled or ingested) are calculated by taking into account the capacity of each module, worker types and numbers, exposure durations, and available shielding. With the aid of the MicroShield computer model (Grove Engineering, 1992), a "unit" EDE is calculated for workers within each module. MicroShield modeling is performed assuming that a unit concentration (1 $Ci/m^3$) of each radionuclide is present. Since treatment periods are assumed for a maximum of 10 years, radioactive decay and ingrowth of daughter products are considered for a five-year time period (average of the treatment period) in order to include external doses from photon-emitting daughter products.

### D.2.8 Calculating Risks

This section describes how the unit doses and intakes estimated by modeling (as described in the previous section) are scaled up according to each site's source term and how the PEIS human health risk estimates are calculated for the various alternatives.

### D.2.8.1 Scaling Unit Doses and Intakes According to Installation Source Term

For each site, a database is created of unit doses and intakes for all known contaminants. The database comprises numerous tables that contain waste-, site-, and exposure pathway-specific information. For radionuclides, the database contains tables of unit doses by site, receptor, contaminant, and pathway. For chemicals, the database contains tables of unit intakes by site, receptor, contaminant, and pathway.

Once unit doses and intakes have been estimated for the contaminants at a particular site for a particular alternative, they are scaled up based on the waste inventory at that site. To estimate exposures to the offsite and noninvolved populations, intruder, and farm family posed by a particular contaminant at the site, the inventory for that contaminant is first multiplied by the fraction of contaminant released during treatment, storage, and disposal activities. This product, the source term, is the estimated amount of contaminant released to the environment that could result in exposure via ingestion or inhalation. To estimate worker exposures, the unit exposure values are scaled by the inventory of contaminant present in each module for a particular site.

### D.2.8.2 Calculating Risks From Unit Doses and Intakes

**Calculating Risks for Noncarcinogens**. The health risk value for each noncarcinogenic hazardous chemical is estimated by dividing the intake by the appropriate chemical-specific toxicity value (e.g., the EPA RfD) for all receptors but waste management workers. For workers, the estimated air concentration is divided by the ACGIH TLV. The resulting quotients (called the "hazard quotient" and "exposure ratio," respectively) express how closely the exposure to this toxicant, under the conditions in the exposure scenario, approaches the EPA or ACGIH exposure standard (this concept is explained in greater detail in Sections D.2.9, D.2.10, and D.2.11).

**Calculating Risks for Carcinogens**. Risks for carcinogens are estimated by multiplying the unit dose or intake by the appropriate cancer risk values from the EPA and the ICRP. For chemical carcinogens, EPA chemical-specific cancer potency factors are used (EPA, 1991b). The risk factors used for radionuclides are published in *ICRP 60* (ICRP, 1990). The radiological risk factors for the public (all receptors except waste management workers) and waste management workers are shown in Table D.2–3.

***Table D.2-3. ICRP Radiological Risk Factors Used in the PEIS Human Health Risk Evaluation***

| Endpoint | Risk Factor for Public Receptors[a] | Risk Factor for Workers |
|---|---|---|
| Cancer incidence | 0.0017/rem-lifetime | 0.0014/rem-lifetime[b] |
| Cancer fatality | 0.0005/rem-lifetime | 0.0004/rem-lifetime[b] |
| Genetic effects | 0.0001/rem-lifetime[c] | 0.00006/rem-lifetime[c] |

[a] Public receptors include offsite population and noninvolved workers.
[b] The nominal probability coefficient for fatal cancers is used to derive the cancer incidence nominal probability coefficient. The probability of fatal cancer, F (which for workers is 80% of F, as described in *ICRP 60*) is divided by the lethality fraction, k, for each organ. The total cancers per organ are then summed over all organs to result in total cancer incidence nominal probability coefficient of 0.0014.
[c] Includes weighting for severity of hereditary effects, but not for years of life lost should harm occur.

Source: ICRP (1990).

As stated above, these factors are multiplied by the EDE or committed EDE (for internal radiological exposures) sustained by a receptor or group of receptors to yield risk estimates associated with radiation exposure. The *ICRP 60* risk factors are consistent with the recommendations of the DOE Office of National Environmental Policy Act Oversight and are contained in the preamble to the U.S. Nuclear Regulatory Commission's Standards for Protection Against Radiation, 56 *Fed. Reg.* 23363.

In comparing the risks from radionuclide exposures with the risks from chemical carcinogen exposures, it is important to note that radionuclide and chemical carcinogen risks are determined by different methods. The dose conversion factors and risk factors used to estimate radionuclide-associated risks are based on observed potency in humans (typically studies of atomic bomb victims). The slope factors used to estimate chemical-carcinogen-associated risks are derived from animal studies and believed to be more conservative as a result of the uncertainty in extrapolating results for humans. These differences in risk estimation should be considered when comparing radionuclide and chemical carcinogen risks.

**Risk Factors for Construction and Operational Hazards.** Construction and operational risks are calculated based on current Bureau of Labor Statistics and National Safety Council statistics for the number of construction fatalities per 100,000 full-time workers; the rate of injuries, illnesses, or lost work days per 100 full-time workers over 200,000 work hours; and the risk of operational fatality, illness, or injury to

sanitary (sewerage and refuse) services workers (including both government and private industry employees).

**Calculating Risks to the Public (All Receptors Except Waste Management Workers).** The following example summarizes the steps involved in calculating risk for the offsite population:

- **Calculating Unit Dose**—Assuming that 1 Ci of plutonium–238 is released per year from one treatment module in LLW Treatment Facility No. 2 at Site X, a unit dose of 0.0001 rem/Ci/year is calculated, using the computer model GENII, for inhalation of plutonium–238 by the offsite population.

- **Calculating Exposure to Public Receptors**—The unit dose of 0.0001 person-rem/(Ci/year) is multiplied by the source term, which is the inventory of plutonium–238 (expressed in Ci) released per year. Assuming that the source term for plutonium–238 emissions from one treatment module in LLW Treatment Facility No. 2 at Site X is 20 Ci/year:

$$0.0001 \text{ person-rem/(Ci/year)} \times 20 \text{ Ci/year} = 0.002 \text{ person-rem} \qquad \text{(D.2-1)}$$

- **Calculating Annual Risk of Cancer Fatalities**—The annual risk for cancer fatalities resulting from the release of plutonium–238 from one treatment module in LLW Treatment Facility No. 2 at Site X is calculated by multiplying the dose calculated in equation (1) above by the risk factor for cancer fatalities for the offsite population (Table D.2–3) to obtain the annual risk for release of plutonium–238 from one treatment module in LLW Treatment Facility No. 2 at Site X:

$$0.002 \text{ person-rem} \times 0.0005\text{/person-rem} = 0.000001 \text{ (or one in one million)} \qquad \text{(D.2-2)}$$

- **Calculating Cumulative Risk for Entire Release Period**—To calculate the cumulative cancer fatality risk release of plutonium–238 from one treatment module in LLW Treatment Facility No. 2 at Site X for the entire 20-year release period, the annual risk calculated in equation (2) above is multiplied by 20:

$$0.000001\text{/year} \times 20 \text{ years} = 0.00002 \text{ (or 2 in 100,000) over 20 years} \qquad \text{(D.2-3)}$$

The risks for all of the contaminants in the site's source term are calculated as described in the four steps above, then summed to yield the total risk for each exposure pathway. The risks for each pathway

associated with a treatment module are summed to give a risk for each module. The risks for all modules are summed to give a risk for each waste type. The risks for treatment of each waste type at a site can then be summed to give the site's total risk. Population risk estimates represent the estimated number of occurrences of a health effect such as cancer incidence, cancer fatality, or genetic effects within the total population. A risk estimate for an individual (i.e., for the MEIs) is the estimated probability that the individual will develop a particular health effect.

**Calculating Risks to Waste Management Workers**. Risks to waste management workers from exposure to a unit amount of contaminant are estimated using unit doses similar to the those described above. Worker risks are calculated by the following steps:

- Waste management modules, treatment trains, worker types, and staffing estimates are characterized as described in Section D.2.7.2.
- Unit doses and intakes for each technology or module are then calculated.
- Worker exposures are estimated based on unit intakes and doses, site/module-specific contaminant inventories and waste throughputs, and module-specific person-hours required to perform the selected technologies or activities.
- The risks of injury and death from physical trauma (crushing, burning, electrocution, etc.) during construction and operation of waste management facilities are calculated based on worker person-hours and current Bureau of Labor Statistics and National Safety Council data, as described in Section D.2.8.1 and the ORNL worker risk methodology (ORNL, 1995b).

For example, assume that a rate of 0.00005 deaths per person-hour from physical trauma is expected for workers involved in heavy construction. If an estimated 20,000 person-hours are required to build a treatment facility, then:

$$20{,}000 \text{ person-hours} \times 0.00005 \text{ deaths/person-hour} = 1 \qquad \text{(D.2-4)}$$

Therefore, one death is estimated to occur during facility construction.

### D.2.9 Calculating and Interpreting the Hazard Index

The hazard index is an indicator of the total *additive*, noncancer toxicity from exposure to mixtures of hazardous chemicals (EPA, 1991a). It is calculated for the offsite and noninvolved worker MEIs at each site, by alternative, for both routine waste management operations and potential accidents. The highest offsite and noninvolved worker hazard indices for a particular alternative represent the estimated highest noncarcinogenic chemical exposure that an offsite individual and individual noninvolved worker, respectively, would receive at any site under that scenario.

The first step in calculating the hazard index is to estimate the receptor's predicted exposure to a hazardous chemical in the waste mixture, and divide the predicted exposure level by that chemical's maximum acceptable level (the level to which a person can be exposed 24 hours/day over a 70-year lifetime without developing adverse effects). These maximum acceptable levels are determined based on EPA RfDs and RfCs.

The resulting number from this calculation is the "hazard quotient." Hazard quotients are calculated for all of the hazardous components in the mixture and the results are summed to yield the hazard index.

Hazard index estimates should be interpreted according to EPA risk assessment guidelines (EPA, 1991a). According to this guidance, if the hazard index is less than or equal to 1.0, the exposure is unlikely to produce adverse toxic affects. However, the closer the hazard index is to 1.0, the more concern about the potential hazard of the chemical mixture increases. If the index exceeds 1.0, the concern is the same as if an individual chemical exposure had exceeded its acceptable level by the same proportion. While the hazard index does not provide a statistical probability that a particular mixture at a particular exposure level will cause a particular adverse effect (recall that below-threshold exposures for single components of a mixture may not contribute to adverse effects), it can serve as an indicator of the *relative potential for causing harm.* For a more detailed explanation of this concept, refer to supporting technical reports by ORNL (1995b,c).

If a contaminant has no RfD, it is excluded from the public risk analysis and the effect of excluding it is discussed in the results.

### D.2.10 Calculating and Interpreting the Exposure Index

For routine waste management operations, the exposure index is calculated for the maximally exposed FTE ("worker equivalent") instead of the hazard index. Like the hazard index, the exposure index is an estimate of the greatest total noncancer toxicity from exposure to hazardous chemicals (EPA, 1991a). However, it is based on occupational exposure (which is episodic) rather than continuous, residential-type exposure.

The first step in determining the exposure index is to divide the concentration of each hazardous chemical in the workroom air by its TLV to yield an "exposure ratio" for each chemical. TLVs are typically time-weighted average exposure concentrations considered safe for a normal 8-hour (or 10-hour) work day and a 40-hour work week. The TLVs for an 8-hour work day were used for this analysis when available (ACGIH, 1992).

The exposure ratios for all of the chemicals in the workroom air are summed to determine the exposure index. Results greater than 1.0 indicate exposure at levels higher than recommended and an increased likelihood of adverse health effects. Similar to the hazard index, the exposure index in the results shows the highest chemical exposure to the maximally exposed FTE at any site under a particular alternative.

If no TLV or IDLH concentration has been determined for a particular contaminant, it is not included in the worker risk estimates. If an excluded contaminant comprises a significant percentage of the waste, the results discussion for that waste addresses the effect of excluding it.

### D.2.11 Calculating and Interpreting the IDLH Index for Accidents

For *accidents* involving hazardous, noncarcinogenic wastes, the IDLH index (NIOSH, 1992), instead of the exposure index, is determined for FTEs. The IDLH index is similar in concept to the exposure index and is calculated similarly for the maximally exposed FTE at any site under a particular alternative. However, it is based on comparison to contaminant air concentrations that impair escape or are immediately dangerous to life and health if exposure lasts more than 30 min. An IDLH index greater than 1.0 indicates an increased likelihood of immediate danger to life and health (whereas an exposure index greater than 1.0 indicates exposure at a level higher than recommended for a safe work environment). The IDLH index is used for accidents based on the assumption that if exposure to a contaminant does not impair escape or

threaten health or life for at least 30 min, this exposure does not impair escape or threaten health or life in the few seconds or minutes postulated for the accident scenarios analyzed in this part of the PEIS.

### D.2.12 Assessing the Risks From Potential Accidents

This section provides a brief overview of the methodology for calculating accident risks; additional details can be found in (ORNL, 1995b).

There are two general types of accidents likely to affect waste management operations: operational accidents involving waste management workers in the course of routine waste management activities; and external events, which are accidents caused by forces or events outside of waste management operations. Operational accidents include handling mishaps, explosions, uncontrolled reactions, fires, and leaks or spills. External events include those caused by humans (such as airplane crashes) and natural phenomena (such as earthquakes, extreme winds or tornadoes, and volcanoes). One or more of these types of accidents were postulated and evaluated for all WM Program waste types as part of the PEIS human health risk analysis. The rationale for the design and selection of the PEIS accident scenarios can be found in Appendix F. In general, accidents for which the attendant risks are potentially highest (such as an earthquake followed by fire and explosion) and accidents that are likely to occur during waste management operations (such as drum-handling accidents) have been selected to represent the spectrum of potential accidents.

In all accident scenarios, one shift of workers is assumed to be present in the facility when the accident occurs. The workers are assumed not to be using personal protective equipment because adequate engineering and administrative controls are assumed to be in place to protect them during routine operations. It is assumed that workers are not blocked or injured by falling or burning debris, and are not so overcome by heat or smoke that they cannot escape from the accident scene. The injuries or fatalities considered in the risk analysis result solely from the radiological and/or chemical exposure the workers receive in the accident.

It is assumed that when an accident occurs, the released contaminants mix uniformly into a specified volume of air. The size and shape of this volume vary according to waste type and accident scenario. The concentration of contaminants in this volume of air is the concentration to which workers are exposed. Exposure durations vary depending on the type of accident and whether it occurs indoors or outdoors. Any

contamination that escapes during the accident is assumed to disperse to the offsite and noninvolved worker populations via the atmosphere. Both populations are at risk from inhaling contaminated air. In addition, the offsite population may be directly exposed by contaminated soils, and by ingesting contaminated water, soil, meat, and agricultural products (ORNL, 1995a). The resulting health effects and their duration depend on the type of contaminant(s) released and the exposure pathway(s) and route(s) (ORNL, 1995a). Because the exposure pathways and routes may be different for the offsite and noninvolved worker populations than for workers, the contaminant of greatest concern to these nonworker populations may be different from the contaminant causing the most risk to workers.

The population distributions and meteorological monitoring data used in the accident analyses can be found in the technical report, "PEIS Installation Descriptions" (ORNL, 1995d). Any additional assumptions used in evaluating accident risks are noted in the text where appropriate.

### D.2.12.1 Predicted Annual Frequency of Accidents

Each accident type in the PEIS risk evaluation is assigned an estimated annual frequency of occurrence as follows (see Appendix F):

- Anticipated (greater than 1 chance in 100 years)
- Unlikely (between 1 chance in 100 and 1 chance in 10,000 years)
- Very unlikely (between 1 chance in 10,000 and 1 chance in 1,000,000 years)
- Extremely unlikely (less than 1 in 1,000,000 years)

For example, incinerator ash explosions during the processing of LLW are considered to be anticipated, while a large aircraft impact with resulting fire and explosion is considered extremely unlikely.

The accident risk estimates presented in the results section reflect only the *consequence* of each accident as though it occurs; the estimated annual frequency is not factored into these results. However, when considering the results, readers should bear both of these parameters in mind. There may be cases in which an accident scenario has extremely serious projected consequences but the probability that it will occur is extremely remote. Conversely, an accident with relatively small consequences may be of substantial concern because it is predicted to occur relatively often.

### D.2.13 Contents of the Risk Analysis Tables

The risk analysis results tables in the subsequent sections of this appendix present a breakdown of the total human health risks associated with managing and disposing of that waste under its waste consolidation alternatives. For each of the waste types, the tables show:

- The estimated risk to each total offsite and noninvolved worker population, their respective MEIs, and waste management workers of developing cancer, dying of cancer, or suffering adverse genetic effects from exposure to chemicals and/or radionuclides, by alternative and site
- The risks to waste management workers of death or injury from physical trauma during waste management activities and the construction of waste management facilities, by alternative and site (it is assumed that no contaminants are released during these events so physical hazards can be assessed separately from chemical and radiological hazards)
- A hazard index calculation for the offsite and noninvolved worker MEIs, indicating the greatest likelihood of noncancer toxicity from continuous exposure to chemical contaminants, by alternative
- An exposure index calculation for the maximally exposed FTE (hypothetical worker or "worker equivalent"), indicating the greatest likelihood of noncancer toxicity effects from work-day (episodic) exposure to chemical contaminants, by alternative
- The risks to waste management workers, the maximally exposed generation of the hypothetical farm family, and all generations of the farm family from disposal of LLW and LLMW, by alternative and site
- The risks to the hypothetical intruder for intrusion at 100 years and 300 years, by alternative
- The risks to all populations and MEIs from potential accidents, by alternative

### D.2.14 Reading and Interpreting the Risk and Probability Numbers

The numbers in the results tables are displayed in the standard "scientific" (exponential) notation used in risk assessment and are read as follows. Assume that a table contains the entry 5.0E–01 to represent the total estimated operations fatalities to waste management workers incinerating a particular waste under a Regionalized Alternative. The notation "E–01" indicates the power of 10 by which the leftmost, two-digit number (in this case, 5.0) is to be multiplied. Therefore, 5.0 is multiplied by $10^{-1}$ (0.1) to yield 0.5. This result means it is predicted that nationwide operations for that waste type under this Regionalized Alternative will result in an estimated 0.5 fatality during routine incineration operations over the total processing period for that waste (e.g., 10 or 20 years). Note that the estimate in this example is a fraction

of 1, that is, a number less than 1. This means that over the period studied (under the assumptions used in the risk analysis), no waste management workers are estimated to die as a result of routine incinerator operations. (However, note that there is some degree of error in any risk estimate due to uncertainties in the assumptions, data, models, etc., used to perform the analysis; see Sections D.2.15 and D.4).

Probability is expressed as a number between zero and one. If there is no chance that a particular event will occur, it is assigned a probability of zero; if that event is certain to occur, its probability is one. The probability that the offsite and noninvolved worker MEIs will develop or die of cancer, or manifest noncancer toxicity, etc., is expressed in the same notation as risk. Assume that a table contains the entry 3.0E–06 to represent the probability that the noninvolved worker MEI for a particular waste type scenario will develop cancer from exposure to a radioactive waste. The notation 3.0E–06 indicates that 3.0 is multiplied by $10^{-6}$ (0.000001). Therefore, this probability is 0.000003, which means that there are 3 chances in 1,000,000 that, over the total waste processing period, the noninvolved worker MEI will develop cancer from exposure to that radioactive waste. (Again, note that this estimate will be affected by any uncertainties associated with the risk calculations.)

As discussed in preceding sections, the maximum exposure to workers allowed under 10 CFR 835 and DOE Order 5480.11 is 5 rem/year. In contrast, DOE Order 5400.5 states that the maximum annual allowable radiation dose to the members of the public from DOE-operated nuclear facilities is 100 mrem/year. For perspective, it is estimated that the average individual in the United States receives a dose of about 300 mrem (0.3 rem)/year from all sources combined, including medical sources of radiation (such as x-rays) and natural background radiation (such as radon gas). A modern chest x-ray results in a dose of approximately 8 mrem, while a diagnostic hip x-ray results in a dose of approximately 83 mrem. A person must receive an acute (short-term) dose of approximately 600,000 mrem before there is a high probability of near-term death (NAS/NRC, 1990). Another relevant benchmark is the disposal standard for spent nuclear fuel, HLW, and TRUW (40 CFR 191), which states that disposal of these materials in compliance with the containment requirements should not result in MEI doses greater than 15 mrem/yr.

Note that the estimated risks of injury to waste management workers take into account all on-the-job injuries from the most minor to the most severe. Similarly, the risks to all receptors of adverse effects from noncarcinogenic, hazardous chemicals (expressed as the hazard and exposure indices) consider all adverse manifestations with no indication of their severity.

Finally, there are two ways to examine and compare the risks between alternatives in this risk analysis: at the *program level* and at the *site level*. This is illustrated in the following example.

Consider a Decentralized Alternative (for example, Hypothetical Alternative 1) that affects the populations at 14 sites and a Centralized Alternative (Hypothetical Alternative 2) that affects the population at only 1 site. If the total risks across all sites in Hypothetical Alternative 1 are *numerically* higher than the total risks for the one site in Hypothetical Alternative 2, Hypothetical Alternative 1 is the highest-risk alternative at the *program level*. However, the reader may find it useful in some instances to look at these risks at the *site level* as well.

Suppose the overall programwide risk of cancer incidence from radionuclide exposure in Hypothetical Alternative 1 is 8.0E–01, and this total risk is distributed across 23 million people, the sum of the offsite populations at all 14 sites involved in that alternative. If this programwide risk, 8.0E–01, is divided by the total affected population, 23 million, the resulting number is:

$$8.0\text{E–01 (total risk for alternative)} \div 23{,}000{,}000 \text{ people affected overall} = 3.5\text{E–08} \quad \text{(D.2-5)}$$

This result, 3.5E–08, might be considered the "average" risk to an individual member of the programwide offsite population. (Note that this number is *not* the risk to the MEI, and will *in all cases* be less than the risk to the MEI. This is because, on average, individual members of the population receive less exposure, by definition, than the MEI, the maximally exposed member of the population.)

### D.2.15 Overview of Uncertainties in the PEIS Risk Analysis Process

The results of any human health risk assessment are conditional estimates based on multiple assumptions about exposure, toxicity, release of contaminants into the environment, human behavior patterns, and other variables. Therefore, the uncertainties accompanying the analysis should be evaluated to place these risk estimates in proper perspective. Uncertainties can be classified into three broad categories:

- Model uncertainty
- Scenario uncertainty
- Parameter uncertainty

Model uncertainty can result from the general limitations of mathematical models. Modeling involves trying to simulate a process that is inherently complex using a fixed and relatively small number of variables. Model uncertainty is usually estimated in the verification and validation phase of model development. Model uncertainty can also result from the inappropriate application of a model to a particular scenario (for instance, in situations for which no model has been specifically designed, and existing models must be adapted for use).

Scenario uncertainty may result from a generalized or incorrect conceptualization of a contaminant release or an exposure scenario. For example, there may be errors in the generalized assumptions concerning the amount of contaminants released, the spatial distribution of potential receptors, and the intake parameters considered for the receptors.

Parameter uncertainty may result from sampling errors, natural variability of the parameter, or the use of generic data (data that are not site-specific). The fate and transport models used to estimate risks for the PEIS require large amounts of data, including meteorological measurements, hydrogeologic settings, and release parameters. Actual data are used where possible, but generic data are often substituted where site-specific data are unavailable.

Keep in mind that the goal of the PEIS risk analyses is to evaluate the *relative* differences in risks among the various waste management alternatives if implemented nationwide. The assumptions made in performing this program-level evaluation were intended to yield reasonably conservative risk estimates (i.e., estimates that tend to overestimate rather than underestimate risk) using the best available data and state-of-the-art models. Given the programmatic nature of the PEIS and the use of the unit approach to risk assessment (ORNL, 1995c), many of the uncertainties associated with the PEIS risk estimates are "systematic." That is, many modeling and scenario assumptions were applied consistently—that is, "systematically"—throughout the analysis (such as facility emission rates for particular types of waste treatment or storage, inhalation rates, etc.). Therefore, the *relative* differences in risk estimates among waste management alternatives should not be affected by errors associated with these systematically applied assumptions. For example, if consumption of contaminated agricultural food products by the offsite population was overestimated for one alternative, it was similarly overestimated for all other alternatives.

Other uncertainties in risk estimates may be specific to assumptions about a particular scenario or site (such as wind conditions, crop yields, etc.). Section D.4 presents an evaluation of some of these parameter

uncertainties associated with the PEIS health risk estimates. In addition, readers may also wish to refer to the modeling literature cited in the reference list.

## D.3 Risk Analysis by Waste Stream

This section contains a summary of the risk analysis for both routine waste management operations and potential accidents associated with each of the DOE WM Program waste streams. The information for each waste stream includes a brief definition of the waste, an overview of the alternatives analyzed, the special assumptions and considerations used in the analysis, tables showing the results of the analysis, and results summaries.

### D.3.1 High-Level Waste

High-level waste (HLW) is the highly radioactive material resulting from the reprocessing of spent nuclear fuel. When spent nuclear fuel is reprocessed, reactor fuel elements are divided and dissolved to separate plutonium and uranium from their fission products; the plutonium and uranium can then be reused. The byproduct, HLW, includes liquid waste produced directly in reprocessing as well as any solid waste derived from the liquid, and contains a combination of TRUW and fission products in concentrations requiring careful handling and permanent isolation (DOE, 1988). Because a variety of solvents, acids, and alkaline agents are used in spent nuclear fuel reprocessing as well as in treatment, HLW may also contain hazardous waste components (nonradioactive but hazardous substances subject to Resource Conservation and Recovery Act regulation). However, once HLW has been vitrified (vitrification involves mixing the waste with glass-forming frit; heating the mixture to fuse it into a glass, ceramic, or other noncrystalline solid; and storing the immobilized waste in sealed, decontaminated metal canisters), these are no longer present or are immobilized in the glass matrix and are no longer emitted. DOE has determined that spent nuclear fuel reprocessing will be phased out as soon as possible; therefore, liquid HLW will no longer be generated in the future.

Four sites manage DOE-owned HLW (note that the abbreviations given here are used in the tables in this appendix):

- Hanford Site (Hanford), Richland, Washington

- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Savannah River Site (SRS), Aiken, South Carolina
- West Valley Demonstration Project (WVDP), West Valley, New York

Because DOE has already selected vitrification as the method for immobilizing HLW, evaluations were performed only for the worker risks associated with interim storage of the resulting HLW canisters pending final disposal in a national geologic repository. Public risks were not evaluated for interim storage because the offsite population would be at negligible risk of exposure. However, public risks were calculated for potential accidents; the results are presented in Sections D.3.1.5 through D.3.1.7. Transportation risks are presented in Appendix E.

Chapters 3 and 9 of the PEIS and the HLW technical report (ANL, 1996a) provide more detailed information on this waste including HLW inventories at DOE sites, estimated release rates, treatment categories used in the PEIS, and the process for developing the PEIS HLW alternatives.

### D.3.1.1 Summary of HLW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized, and Centralized) and the rationale for developing them are discussed rigorously in the main body of the PEIS. Five HLW alternatives (the No Action, Decentralized, Regionalized 1, Regionalized 2, and Centralized Alternatives) were analyzed. For each alternative, two cases—designated Storage Cases 1 and 2—were analyzed. In Storage Case 1, it was assumed that a geologic repository would be available in 2015 and would accept HLW canisters at a rate of 800/year. In Storage Case 2, it was assumed that there would be a delay in the availability of a geologic repository past 2015, but that when the repository began accepting HLW, it would accept canisters at a rate of 800/year. For each alternative except the Centralized Alternative, the number of canisters produced and stored at each site is identical between Storage Cases 1 and 2. In Storage Case 1 of the Centralized Alternative, Hanford stores only the portion of canisters produced by SRS until 2015; and in Storage Case 2 of the Centralized Alternative, Hanford stores all of the SRS canisters.

- In the No Action Alternative, HLW canisters are stored in existing and approved interim storage facilities at Hanford, SRS, and WVDP. No interim storage facility exists or has been approved for INEL; therefore, no risks are calculated for INEL under the No Action Alternative.

- In the Decentralized Alternative, each of the four sites continues to store its own inventory of immobilized HLW awaiting ultimate disposal in a national geologic repository.
- In the Regionalized Alternative 1, 340 vitrified canisters of HLW from WVDP are shipped to SRS to be stored there until final disposition. Hanford and INEL store their own HLW.
- In the Regionalized Alternative 2, 340 canisters of HLW from WVDP are shipped to Hanford for interim storage. SRS and INEL store their own HLW.
- In Storage Case 1 of the Centralized Alternative, 2,373 canisters from SRS and 340 from WVDP are transported to Hanford for interim storage until a geologic repository is available. The remaining canisters produced at SRS (2,199) are stored onsite until a geologic repository is in operation. In Storage Case 2, Hanford stores all SRS, INEL, and WVDP canisters (a total of 21,612) and would require additional storage capacity.

Construction hazards were analyzed for the sites where additional storage facilities would be needed until the opening of a national geologic repository in the year 2015 or later.

Table D.3.1-1 depicts the five HLW alternatives and shows which sites ship their wastes to regional or central consolidation sites for interim storage. The numbers in parentheses are the numbers of canisters stored at the site. For each alternative, Storage Cases 1 and 2 are identical to one another except in the Centralized Alternative, in which Hanford would store all of the SRS, WVDP, and INEL canisters (making a total of 21,612 HLW canisters at Hanford).

### D.3.1.2 Special Assumptions and Considerations Used in the HLW Risk Analysis

Once HLW has been vitrified, sealed in stainless steel canisters, decontaminated, and moved into dedicated storage, there is expected to be very little risk of exposing the public to these materials under routine (nonaccident) conditions; therefore, only routine operational worker risks associated with interim storage of treated HLW were evaluated. These include risks associated with exposure to radiation and with operational or construction hazards. Risk estimates were based on expected worker person-hours associated with loading and storage activities. Potential exposures and health risks to the public and workers from accidental releases during HLW storage are considered in Sections D.3.1.5, D.3.1.6, and D.3.1.7.

*Table D.3.1-1. PEIS Waste Consolidation Alternatives for HLW*

| Alternative | | Hanford | INEL | SRS | WVDP |
|---|---|---|---|---|---|
| No Action (both storage cases) | Ship | -- | -- | -- | -- |
| | Store | Hanford (750) | -- | SRS[a] (4,572) | WVDP (340) |
| Decentralized (both storage cases) | Ship | -- | -- | -- | -- |
| | Store | Hanford[a] (15,000) | INEL[a] (1,700) | SRS[a] (4,572) | WVDP (340) |
| Regionalized 1 (both storage cases) | Ship | -- | -- | -- | Store temporarily for 6 years then ship 340 to SRS |
| | Store | Hanford[a] (15,000) | INEL[a] (1,700) | SRS[a] (4,912) | |
| Regionalized 2 (both storage cases) | Ship | -- | -- | -- | Store temporarily for 16 years then ship 340 to Hanford |
| | Store | Hanford[a] (15,340) | INEL[a] (1,700) | SRS[a] (4,572) | |
| Centralized—Storage Case 1 | Ship | -- | -- | Ship 2,373 to Hanford | Ship 340 to Hanford |
| | Store | Hanford[a] (17,713) | INEL[a] (1,700) | SRS (2,199) | -- |
| Centralized—Storage Case 2 | Ship | -- | Ship 1,700 to Hanford | Ship 4,572 to Hanford | Ship 340 to Hanford |
| | Store | Hanford[a] (21,612) | -- | -- | -- |

Note: Numbers within parentheses are the numbers of canisters stored at the site.
[a] Construction of a new storage facility is required.

Interim storage is defined as long-term storage prior to disposal in a geologic repository. Temporary storage is defined as more short-term storage prior to shipment to another site for interim storage pending disposal in a geologic repository. For the purposes of this analysis, all shipments of HLW are assumed to be by truck.

It was assumed that the canisters are thoroughly decontaminated before they are transported to interim storage; this would remove any radioactive residue from the outside of a canister that could be inhaled, ingested, or transferred to the skin. Therefore, WM workers would be subject only to radiation that penetrates the HLW canister wall (this is termed "external" or "direct" radiation) and to the physical hazards associated with construction and routine facility operations. It was also assumed that HLW treatment would remove or immobilize any hazardous, nonradioactive components; therefore, there would be little or no risk of chemical carcinogenesis or toxic effects.

### D.3.1.3 Results Tables for the HLW Human Health Risk Analysis

This section contains the results tables for the HLW human health risk analysis. A discussion of the results is presented in Section D.3.1.4. The fatality and cancer incidence numbers in the tables are displayed in

the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.1-2 presents an overview, by alternative (for Storage Case 1 only), of the *total*, programwide risks of cancer fatalities, cancer incidence, and construction and operational fatalities to waste management workers. This table provides the estimated *total number* of workers involved in storage and handling activities who will develop or die of cancers caused by exposure to HLW over the next 50 years if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities associated with storage and handling of HLW.
- Tables D.3.1-3 through D.3.1-7 show the programwide worker risks by health effect and Storage Case 1 alternative.
- Tables D.3.1-8 through D.3.1-12 present the worker population risks for each site, by Storage Case 1 alternative.
- Tables D.3.1-13 and D.3.1-14 present the incremental annual risk for each Storage Case 2 alternative (where the repository opening is delayed past 2015). These risk numbers show the additional risk per year from storage past 2015.
- Table D.3.1-15 presents the additional risks at Hanford for the Storage Case 2 Centralized Alternative. This alternative requires Hanford to accept all canisters of HLW produced at WVDP, INEL, and SRS which will result in more loading and unloading risks and additional construction risks.

***Table D.3.1–2. Summary of Programwide Risks Associated With Routine Management of HLW: Risks to Worker Population Under Storage Case 1, by Alternative***

| Storage Case 1 Alternative | Total Fatalities[a] | CF | CI | C&OF |
|---|---|---|---|---|
| No Action | 3.0 | 2.2 | 7.5E+01 | 8.1E–01 |
| Decentralized | 4.7 | 3.2 | 1.1E+01 | 1.5 |
| Regionalized 1 | 4.8 | 3.3 | 1.1E+01 | 1.5 |
| Regionalized 2 | 4.8 | 3.3 | 1.2E+01 | 1.5 |
| Centralized | 5.0 | 3.4 | 1.2E+01 | 1.6 |

Notes: CF = cancer fatality associated with exposure to radionuclides; CI = cancer incidence; C&OF = construction and operational fatalities.
[a] Sum of fatalities from construction, operation, and cancer associated with exposure to radionuclides.

***Table D.3.1–3. Programwide Risks Associated With Managing HLW Under Storage Case 1 of the No Action Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| WM workers | Dose (FTE-rem) | 5.4E+03 | |
| | Cancer fatalities | 2.2 | |
| | Cancer incidence | 7.5 | |
| | Genetic effects | 3.2E–01 | |
| | Construction fatalities | | 7.9E–03 |
| | Construction injuries | | 3.5 |
| | Operation fatalities | | 8.1E–01 |
| | Operation injuries | | 6.9E+02 |

***Table D.3.1–4. Programwide Risks Associated With Managing HLW Under Storage Case 1 of the Decentralized Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| WM workers | Dose (FTE-rem) | 8.1E+03 | |
| | Cancer fatalities | 3.2 | |
| | Cancer incidence | 1.1E+01 | |
| | Genetic effects | 4.8E–01 | |
| | Construction fatalities | | 1.4E–01 |
| | Construction injuries | | 6.2E+01 |
| | Operation fatalities | | 1.3 |
| | Operation injuries | | 1.1E+03 |

***Table D.3.1–5. Programwide Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 1, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| WM workers | Dose (FTE-rem) | 8.1E+03 | |
| | Cancer fatalities | 3.3 | |
| | Cancer incidence | 1.1E+01 | |
| | Genetic effects | 4.9E–01 | |
| | Construction fatalities | | 1.4E–01 |
| | Construction injuries | | 6.3E+01 |
| | Operation fatalities | | 1.3 |
| | Operation injuries | | 1.1E+03 |

***Table D.3.1–6. Programwide Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 2, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| WM workers | Dose (FTE-rem) | 8.2E+03 | |
| | Cancer fatalities | 3.3 | |
| | Cancer incidence | 1.2E+01 | |
| | Genetic effects | 4.9E–01 | |
| | Construction fatalities | | 1.5E–01 |
| | Construction injuries | | 6.4E+01 |
| | Operation fatalities | | 1.4 |
| | Operation injuries | | 1.2E+03 |

***Table D.3.1–7. Programwide Risks Associated With Managing HLW Under Storage Case 1 of the Centralized Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| WM workers | Dose (FTE-rem) | 8.4E+03 | |
| | Cancer fatalities | 3.4 | |
| | Cancer incidence | 1.2E+01 | |
| | Genetic effects | 5.1E–01 | |
| | Construction fatalities | | 1.7E–01 |
| | Construction injuries | | 7.3E+01 |
| | Operation fatalities | | 1.4 |
| | Operation injuries | | 1.2E+03 |

***Table D.3.1–8. Risks Associated With Managing HLW Under Storage Case 1 of the No Action Alternative, by Site***

| Site | Worker Risks | |
|---|---|---|
| | Total Fatalities[a] | Cancer Incidence |
| Hanford | 1.5 | 3.8 |
| INEL | 0.0 | 0.0 |
| SRS | 1.3 | 3.4 |
| WVDP | 1.2E–01 | 2.8E–01 |
| Total | 3.0 | 7.5 |

[a] Includes fatalities associated with both radiation exposures and physical hazards.

***Table D.3.1–9. Risks Associated With Managing HLW Under Storage Case 1 of the Decentralized Alternative, by Site***

| Site | Worker Risks | |
|---|---|---|
| | Total Fatalities[a] | Cancer Incidence |
| Hanford | 2.5 | 6.1 |
| INEL | 8.0E–01 | 1.6 |
| SRS | 1.3 | 3.3 |
| WVDP | 1.2E–01 | 2.7E–01 |
| Total | 4.7 | 1.1E+01 |

[a] Includes fatalities associated with both radiation exposures and physical hazards.

***Table D.3.1–10. Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 1, by Site***

| Site | Worker Risks | |
|---|---|---|
| | Total Fatalities[a] | Cancer Incidence |
| Hanford | 2.5 | 6.1 |
| INEL | 8.0E–01 | 1.6 |
| SRS | 1.4 | 3.5 |
| WVDP | 7.8E–02 | 1.7E–01 |
| Total | 4.8 | 1.1E+01 |

[a] Includes fatalities associated with both radiation exposures and physical hazards.

*Table D.3.1-11. Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 2, by Site*

| Site | Worker Risks | |
|---|---|---|
| | Total Fatalities[a] | Cancer Incidence |
| Hanford | 2.6 | 6.4 |
| INEL | 8.1E-01 | 1.6 |
| SRS | 1.3 | 3.3 |
| WVDP | 1.0E-01 | 2.3E-01 |
| Total | 4.8 | 1.2E+01 |

[a] Includes fatalities associated with both radiation exposures and physical hazards.

*Table D.3.1-12. Risks Associated With Managing HLW Under Storage Case 1 of the Centralized Alternative, by Site*

| Site | Worker Risks | |
|---|---|---|
| | Total Fatalities[a] | Cancer Incidence |
| Hanford | 3.0 | 7.2 |
| INEL | 8.3E-01 | 1.6 |
| SRS | 1.1 | 2.7 |
| WVDP | 1.0E-01 | 2.3E-01 |
| Total | 5.0 | 1.2E+01 |

[a] Includes fatalities associated with both radiation exposures and physical hazards.

*Table D.3.1-13. Storage Case 2: Incremental Annual Exposure Risks Associated With Storage Beyond 2015, in Risk per Year*

| Storage Case 2 Alternative | Hanford | | | INEL | | | SRS | | | WVDP | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CF | CI | GE | CF | CI | GE | CF | CI | GE | CF | CI | GE |
| No Action | 2.4E-03 | 8.4E-03 | 3.6E-04 | 0.0 | 0.0 | 0.0 | 7.2E-03 | 2.5E-02 | 1.1E-03 | 1.6E-03 | 5.6E-03 | 2.4E-04 |
| Decentralized | 3.6E-02 | 1.3E-01 | 5.4E-03 | 3.2E-03 | 1.1E-02 | 4.8E-04 | 7.2E-03 | 2.5E-02 | 1.1E-03 | 1.6E-03 | 5.6E-03 | 2.4E-04 |
| Regionalized 1 | 3.6E-02 | 1.3E-01 | 5.4E-03 | 3.2E-03 | 1.1E-02 | 4.8E-04 | 7.2E-03 | 2.5E-02 | 1.1E-03 | 0.0 | 0.0 | 0.0 |
| Regionalized 2 | 3.6E-02 | 1.3E-01 | 5.4E-03 | 3.2E-03 | 1.1E-02 | 4.8E-04 | 7.2E-03 | 2.5E-02 | 1.1E-03 | 0.0 | 0.0 | 0.0 |
| Centralized | 5.0E-02 | 1.8E-01 | 7.6E-03 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Notes: CF = cancer fatalities; CI = cancer incidence; GE = genetic effects.

***Table D.3.1–14. Storage Case 2: Incremental Annual Operational Risks Associated With Storage Beyond 2015, in Risk per Year***

| Storage Case 2 Alternative | Hanford | | INEL | | SRS | | WVDP | |
|---|---|---|---|---|---|---|---|---|
| | OF | OI | OF | OI | OF | OI | OF | OI |
| No Action | 1.1E–03 | 9.2E–01 | 0.0 | 0.0 | 3.2E–03 | 2.8 | 7.2E–04 | 6.1E–01 |
| Decentralized | 1.6E–02 | 1.4E+01 | 1.4E–03 | 1.2 | 3.2E–03 | 2.8 | 7.2E–04 | 6.1E–01 |
| Regionalized 1 | 1.6E–02 | 1.4E+01 | 1.4E–03 | 1.2 | 3.2E–03 | 2.8 | 0.0 | 0.0 |
| Regionalized 2 | 1.6E–02 | 1.4E+01 | 1.4E–03 | 1.2 | 3.2E–03 | 2.8 | 0.0 | 0.0 |
| Centralized | 2.3E–02 | 1.9E+01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Notes: OF = operational fatalities; OI = operational injuries and illnesses.

***Table D.3.1–15. Storage Case 2: Additional Loading, Unloading, and Construction Risks at Hanford***

| Storage Case 2 Alternative | Hanford | | | | | | |
|---|---|---|---|---|---|---|---|
| | CF | CI | GE | OF | OI | CnF | CnI |
| Centralized | 4.2E–01 | 1.5 | 6.3E–02 | 6.3E–02 | 5.3E+01 | 6.7E–02 | 2.9E+01 |

Notes: CF =cancer fatalities; CI = cancer incidence; GE = genetic effects; OF = operational fatalities; OI = operational injuries and illnesses; CnF = construction fatalities; CnI = construction injuries and illnesses.

### D.3.1.4 Results of the HLW Human Health Risk Analysis for Routine Operations

In general, there are only slight differences in estimated worker cancer and physical hazard risks among the Storage Case 1 alternatives (in which the repository is assumed to be available in 2015; see Table D.3.1–2 and Tables D.3.1–3 through D.3.1–12). Programwide fatalities from cancer and physical hazards range from 2.3 to 5.8. The risks for each health endpoint differ by about a factor of two. The factors influencing the risks among the alternatives are: (1) the duration of interim storage; (2) the construction of new interim storage facilities at SRS, Hanford, and INEL; and (3) the volumes of HLW at SRS and Hanford. In the Storage Case 2 alternatives, for every year that operation of the repository is delayed past 2015, there are additional storage risks at certain sites depending on the alternative (see Tables D.3.1–13 and D.3.1–14). Table D.3.1–15 shows the additional risks at Hanford as a result of the increased number of canisters being shipped there for storage in the Storage Case 2 Centralized Alternative.

The lowest estimated cancer fatality risks are for the No Action Alternative in Storage Case 1. This is because there are fewer canisters at Hanford and the risks are zero at INEL. The risks for the Storage Case 1 consolidation alternatives (Decentralized, Regionalized, and Centralized) are higher by a factor of about 1.5. This increased risk is due to the relatively long time that SRS, Hanford, and INEL store their canisters—40 to 45 years at all three sites. These long storage periods are based on the assumption that the national geologic repository accepts 800 canisters/year; therefore, average canister shipping rates to the repository are about 400 canisters/year at Hanford and 200 canisters/year at the other sites. Note that in each of these consolidation alternatives, the canisters are moved from one site to another but the total number of canisters at all sites, hence, the total associated risk, stays approximately the same.

The risk of fatalities from physical hazards follows the same trend as the risk of cancer fatalities; Storage Case 1 risks for the Decentralized, Regionalized, and Centralized Alternatives (1.5 to 1.6) are approximately 2 times higher than the risks for Storage Case 1 of the No Action Alternative (8.1E–01). These higher risks are due to the extended loading and storage periods at Hanford and INEL; this means that more person-hours are devoted to storage activities in these alternatives than in the No Action Alternative. Because more HLW is present at SRS and Hanford, the highest estimated risks of total fatalities are associated with these two sites (see Tables D.3.1–8 through D.3.1–12).

### D.3.1.5 Special Assumptions and Considerations Used in the HLW Accident Analysis

This section presents an overview of the types of potential accidents analyzed for the interim storage of immobilized HLW. For this analysis, ANL estimated source terms for the HLW facilities at Hanford and INEL for accidents involving a canister breach due to dropping, collision, or both. These accident source terms are site-specific but do not differ by alternative (i.e., a glass canister breach at a particular site is considered to have the same consequences regardless of the alternative under which the accident occurs). The probability or frequency of HLW accidents is not addressed. Instead, consequences are presented as if each accident occurs once over the course of HLW interim storage. However, this should *not* be construed as indicating the actual probability or frequency of the postulated storage accidents.

Two accident scenarios were evaluated to determine the risks from radiological exposure to the offsite population and MEI, the noninvolved worker population and MEI, and waste management workers. In both, it was assumed that one canister of vitrified HLW is breached inside the storage facility and produces

a cloud of pulverized, radioactive material. One shift of four waste management workers is assumed to be inside the facility when the accident occurs.

When the canister is breached, the contaminants are assumed to disperse in a hemispherical mixing volume with a radius of 5 m. The four waste management workers are 1 m away from the canister when it is breached and walk away at 1 m/s; therefore, the workers are exposed for 4 sec. It is assumed that the workers do not hold their breath while walking away. While immersed in the resulting cloud of contaminated air, the workers are subject to external radiation and to internal radiation exposure by inhalation.

In the first accident, the storage facility's high-efficiency particulate air (HEPA) filtration system is assumed to be fully functional when the canister is breached and only a small amount of the cloud of contaminated air escapes from the building. This material is atmospherically dispersed and presents a risk of internal and external exposure to the offsite and noninvolved worker populations and their respective MEIs.

In the second accident, the storage facility's HEPA filtration system is assumed to be completely disabled when the canister is breached. The entire cloud of contaminated air escapes from the building, is atmospherically dispersed, and presents a risk of internal and external exposure to the offsite and noninvolved worker populations and their respective MEIs.

For the worker exposure assessment, it was assumed that workers are always exposed to unfiltered releases, thus, the same unfiltered source term was used for both accident scenarios. As a result, worker risks are the same for both accident types at a particular site. The methodology and models for estimating worker risks are different from those used to estimate the risks that noninvolved worker and offsite receptors might receive from atmospheric releases (ORNL, 1995b). Because of this, air concentrations are different for workers than for nonworkers; controlling contaminants and exposure routes may also differ.

### D.3.1.6 Results Tables for the Risk Analysis of Potential HLW Accidents

Table D.3.1–16 presents a programwide summary of the risks of cancer incidence and cancer fatality to all receptors, by accident type and site. Table D.3.1–17 provides the sizes of the offsite, noninvolved worker, and worker populations for each site. Table D.3.1–18 lists the contaminant contributing the most risk to the total offsite population and the dose contributed by that contaminant.

***Table D.3.1–16. Summary of Risks From Potential HLW Accidents, by Accident Type and Site***

| Accident | Site | Offsite Population | | Offsite MEI | | Noninvolved Worker Population | | Noninvolved Worker MEI | | Workers[a] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CF | CI | CF | CI | CF | CI | CF | CI | CF | CI |
| Filtered canister breach | Hanford | 6.7E–06 | 2.3E–05 | 1.6E–10 | 5.3E–10 | 1.5E–07 | 5.2E–07 | 1.5E–09 | 5.1E–09 | 7.1E–03 | 2.5E–02 |
| | INEL | 1.5E–07 | 5.2E–07 | 1.8E–11 | 6.0E–11 | 5.6E–09 | 1.9E–08 | 3.3E–12 | 1.1E–11 | 4.8E–04 | 1.7E–03 |
| Unfiltered canister breach | Hanford | 3.3 | 1.1E–01 | 7.8E–05 | 2.6E–04 | 7.6E–02 | 2.6E–01 | 7.5E–04 | 2.6E–03 | 7.1E–03 | 2.5E–02 |
| | INEL | 7.7E–02 | 2.6E–01 | 8.9E–06 | 3.0E–05 | 2.8E–03 | 9.5E–03 | 1.7E–06 | 5.7E–06 | 4.8E–04 | 1.7E–03 |

Notes: MEI = maximally exposed individual; CF = risk of cancer fatality associated with radiological exposure; CI = risk of cancer incidence associated with radiological exposure.
[a] Worker exposures for a particular site are the same in both accidents.

***Table D.3.1–17. Size of Offsite, Noninvolved Worker, and Worker Populations Affected by the Risks From Potential HLW Storage Accidents, by Site***

| Site | Offsite Population | Noninvolved Worker Population | Worker Population |
|---|---|---|---|
| Hanford | 377,645 | 8,674 | 4 |
| INEL | 153,061 | 8,451 | 4 |

***Table D.3.1–18. HLW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population, by Accident Type and Site***

| Accident Type | Radionuclide and Dose, by Site | |
|---|---|---|
| | Hanford | INEL |
| Filtered canister breach | Strontium-90<br>7.1E–03 person-rem | Cesium-137<br>1.9E–04 person-rem |
| Unfiltered canister breach | Strontium-90<br>3.6E+03 person-rem | Cesium-137<br>9.4E+01 person-rem |

Note: All exposures received via internal exposure (inhalation and ingestion).

### D.3.1.7 Summary of the HLW Accident Analysis Results

As expected, the risks to all offsite and noninvolved worker receptors from the accident in which HEPA filtration is lost are markedly higher than the risks from the accident in which filtration is retained. As shown in Table D.3.1–16, estimated cancer incidence and fatalities for both populations and MEIs are 5 to 6 orders of magnitude greater for the unfiltered canister breach than for the filtered accident.

In the filtered canister breach, cancer incidence and fatality risks to all offsite and noninvolved worker MEI receptors are 1 to 5 orders of magnitude below 1.0E–06. In the unfiltered canister breach, cancer incidence and fatality risks exceed 1.0E–04 for the noninvolved worker MEI at Hanford, and are in the E–06 to E–05 range for the offsite and noninvolved worker MEIs at INEL.

In both accident scenarios, strontium–90 contributes most of the offsite population risk at Hanford and cesium-137 is the major contributor at INEL (see Table D.3.1–18). In both circumstances, the predominant exposure route is inhalation.

Worker exposure is the same in both accident scenarios (see Table D.3.1–16). Worker risks do not differ appreciably between the sites, and are highest at Hanford by less than 0.5 order of magnitude. The controlling radionuclides for worker exposure are strontium-90 at INEL and americium-241 at Hanford; inhalation is the principal exposure route.

## D.3.2 Low-Level Waste

This section contains the human health risk analysis results for low-level waste (LLW). LLW includes all radionuclide-containing wastes not classified as high-level waste, transuranic waste with an activity greater than 100 nanocuries (billionths of a curie) per gram, spent nuclear fuel, or byproduct material as defined in Section 11e(2) of the Atomic Energy Act of 1954 (such as tailings containing uranium or thorium). Waste designated as LLW contains source, special nuclear, or byproduct material that is acceptable for disposal in a land disposal facility and does not contain hazardous components regulated under the Resource Conservation and Recovery Act (RCRA). LLW that contains hazardous components is classified as low-level mixed waste, which is addressed in Section D.3.5.

DOE generates LLW primarily in research and development, defense activities, uranium enrichment operations, and the naval nuclear propulsion program. About 30 sites within the DOE complex generate LLW, including those listed below:

- Argonne National Laboratory-East (ANL-E), Argonne, Illinois
- Argonne National Laboratory-West (ANL-W), Idaho Falls, Idaho
- Brookhaven National Laboratory (BNL), Brookhaven, New York
- Fernald Environmental Management Project (FEMP), Fernald, Ohio
- Hanford Site (Hanford), Richland, Washington
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Kansas City Plant (KCP), Kansas City, Missouri
- Knolls Atomic Power Laboratory-Kesselring (KAPL-K), Schenectady, New York
- Lawrence Berkeley Laboratory (LBL), Berkeley, California
- Lawrence Livermore National Laboratory (LLNL), Livermore, California
- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Mound Plant (Mound), Miamisburg, Ohio
- Naval Reactors Facility (NRF), Idaho Falls, Idaho
- Nevada Test Site (NTS), Las Vegas, Nevada
- Oak Ridge Institute for Science and Education (ORISE), Oak Ridge, Tennessee
- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee (comprises the Oak Ridge K-25 Site [K-25], the Oak Ridge National Laboratory [ORNL], and the Oak Ridge Y-12 Plant [Y-12])
- Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky
- Pantex Plant (Pantex), Amarillo, Texas
- Pinellas Plant (Pinellas), Largo, Florida
- Portsmouth Gaseous Diffusion Plant (PORTS), Piketon, Ohio
- Rocky Flats Environmental Technology Site (RFETS), Golden, Colorado
- Sandia National Laboratories–New Mexico (SNL-NM), Albuquerque, New Mexico
- Sandia National Laboratory–California (SNL-CA), Livermore, California
- Savannah River Site (SRS), Aiken, South Carolina
- West Valley Demonstration Project (WVDP), West Valley, New York

This list includes the 16 major sites considered for LLW management described in Section 1.6.1 and Chapter 7 of Volume I and presented in Table D.3.2–1.

## *Table D.3.2–1. PEIS Alternatives for LLW*

| Alternative | Treat | Dispose | ANL-E | BNL | FEMP | Hanford | INEL | LANL | LLNL | NTS | ORR | PGDP | Pantex | PORTS | RFETS | SNL-NM | SRS | WVDP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action | 10[a] | 6 | | | | TD | TD | D | T | D | TD | T | | | T | | TD | |
| Dec. | | 15 | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D |
| Reg. 1 | | 11 | | | D | D | D | D | D | D | D | D | D | D | D | | D | |
| Reg. 2 | 11 | 11 | | | TD | TD | TD | TD | TD | D | TD | TD | TD | TD | TD | | TD | |
| Reg. 3 | | 6 | | | | D | D | D | | D | D | | | | | | D | |
| Reg. 4 | 7 | 6 | | | | TD | TD | TD | | D | TD | | | T | T | | TD | |
| Reg. 5 | 4 | 6 | | | | TD | TD | D | | D | TD | | | | | | TD | |
| Reg. 6 | | 2 | | | | D | | | | | | | | | | | D | |
| Reg. 7 | | 2 | | | | | | | | D | | | | | | | D | |
| Cen. 1 | | 1 | | | | D | | | | | | | | | | | | |
| Cen. 2 | | 1 | | | | | | | | D | | | | | | | | |
| Cen. 3 | 7 | 1 | | | | TD | T | T | | | T | | | T | T | | T | |
| Cen. 4 | 7 | 1 | | | | T | T | T | | D | T | | | T | T | | T | |
| Cen. 5 | 1 | 1 | | | | TD | | | | | | | | | | | | |

Notes: T = treatment site. In this context, treatment entails volume reduction using thermal organic destruction, size reduction (shredding, etc.), and compaction followed by solidification. All sites perform minimum treatment in all alternatives; this consists of solidifying liquids and powdered material, packaging, and shipment. D = disposal site. Each of the 6-site disposal alternatives uses the same sites, and each of the 12-site disposal alternatives uses the same 12 sites. Dec. = Decentralized; Reg. = Regionalized; and Cen. = Centralized.

[a] Ten sites use existing facilities for volume reduction. Three sites not listed as major sites above (LBL, RMI, and Mound) include volume reduction facilities.

Note that treatment risks were estimated separately in this section of the WM PEIS for the three sites comprising ORR (e.g., ORNL, Y-12, and K-25) based on the assumption that Y-12 and K-25 perform only the packaging and certification/shipment modules, while ORNL undertakes these plus additional modules such as aqueous treatment, solidification, tumulus disposal, and incineration (where applicable). Disposal risks were calculated for the combined three sites based on the assumption that disposal of LLW from all three sites takes place at one central ORR facility.

Treatment sites were also estimated separately later in this section in Tables D.3.2–20 through D.3.2–32 for several other sites in addition to the 16 major LLW management sites. These sites include KAPL-K, LBL, KCP, Mound, and Pinellas. In Chapter 7 of Volume I, treatment risks for ORNL, ORISE, K-25, and Y-12 have been combined and presented under ORR; ANL-W and NRF have been combined with INEL; and SNL-CA has been combined with LLNL. Treatment risks at the remaining smaller sites are contained in the programwide risk tables presented in this section (Tables D.3.2–7 through D.3.2–19) and in the alternative summary risk tables presented in Section 7.4 of Volume I.

LLW may contain a wide range of radionuclides at activities ranging from trace amounts to thousands of curies. Depending on its chemical and physical properties, LLW can be grouped into waste stream categories according to the type of treatment needed, such as dilute and aqueous wastes; organic wastes; combustible wastes; noncombustible, compactible or noncompactible wastes; surface-contaminated bulk metal or equipment; activated bulk metal or equipment; sludges and resins; and remote-handled LLW (RH–LLW), a high-activity waste requiring special handling.

Currently, Hanford, INEL, LANL, NTS, ORR, and SRS are authorized to dispose of DOE-generated LLW. Low-activity wastes can be disposed of by shallow, engineered land disposal; higher-activity wastes require disposal technologies offering greater confinement.

Chapters 3 and 7 of the PEIS and the LLW technical report (ANL, 1996c) provide more detailed information on this waste, including LLW inventories at DOE sites, estimated release rates, treatment categories used in the PEIS, the process for developing PEIS LLW alternatives, and the various waste consolidation alternatives.

### D.3.2.1 Summary of LLW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized 1 and 2, and Centralized) and the rationale for developing them are discussed rigorously in the main body of the PEIS. A broad range of alternatives are analyzed for this waste type:

- The No Action Alternative: All sites transport LLW to six sites (Hanford, INEL, LANL, NTS, ORR, and SRS) for disposal under current arrangements. All sites use existing treatment facilities.
- The Decentralized Alternative: Twelve sites dispose of all LLW projected to be generated over the next 20 years. Minimum treatment at each site is assumed.
- The Regionalized Alternatives (seven alternatives): Two, six, or ten sites dispose of all LLW projected to be generated over the next 20 years. In three of these alternatives, treatment to reduce waste volume (by shredding, compaction, and incineration) is performed.
- The Centralized Alternatives (five alternatives): One site (Hanford or NTS) disposes of all LLW projected to be generated over the next 20 years. In three of these alternatives, treatment to reduce volume is performed.

This series of alternatives makes it possible to compare the risks of minimum treatment versus minimum treatment plus volume reduction, the risks of using volume reduction at varying numbers of sites, and the risks associated with various disposal configurations. Table D.3.2–1 depicts the overall treatment and storage schemes for the LLW Alternatives.

### D.3.2.2 Special Assumptions and Considerations Used in the LLW Risk Analysis

For all disposal scenarios, it is assumed that shallow land burial will be used at sites west of the Mississippi River and tumulus (above-ground vault) disposal will be used at eastern sites. The exceptions are RFETS, which disposes in tumulus vaults, and SRS, which disposes in below-ground vaults.

Some LLW waste streams will already be disposed of onsite and are not considered in the consolidation alternatives. In particular, grout waste at Hanford and saltstone waste at SRS are not included in the LLW disposal inventories at their respective sites. Disposal of these waste forms is assumed to cause no risk to workers because the waste is piped directly into underground disposal facilities; therefore, worker risks have not been assessed for these situations.

It is assumed that, except in the No Action Alternative, LLW disposal capacity at each site will be expanded as required to meet disposal demands.

In estimating worker radiological risks, it is assumed that management and disposal of the "activated metals" and "remote-handled" categories of LLW require greater shielding for workers than the other categories because these two waste streams emit higher levels of external radiation; a remote shielding scenario was used to estimate worker radiation exposure, as described in ORNL unit risk methodology (ORNL, 1995c).

### D.3.2.3 Results Tables for the LLW Human Health Risk Analysis

This section contains tables that summarize the results for the LLW human health risk analysis. A discussion of the results and the remainder of the results tables are presented in Section D.3.2.4. The fatality and cancer incidence numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.2–2 presents an overview, by alternative, of the *total*, programwide risks associated with treatment of LLW. Included are the risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste treatment. This table provides the estimated *total number* of people in the three populations who will develop or die of cancer caused by exposure to LLW if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities. The results in this table are drawn from Tables D.3.2–7 through D.3.2–19 on the following pages.
- Table D.3.2–3 presents an overview, by alternative, of the programwide risks associated with disposal of LLW. This table summarizes the risks of cancer fatalities and cancer incidence for the maximally exposed lifetime (MEL) of the hypothetical farm family; the total risks to members of all 143 lifetimes of the farm family; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste disposal. The results in this table are drawn from Tables D.3.2–33 through D.3.2–46.
- Table D.3.2–4 shows the sizes of the total affected populations for each alternative.

- Table D.3.2–5 summarizes the risks to the noninvolved worker and offsite MEIs for each LLW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will die of cancer or develop cancer from radionuclide exposure. These results are drawn from Tables D.3.2–7 through D.3.2–19 and Tables D.3.2–33 through D.3.2–46.
- Table D.3.2–6 lists the radionuclides that contribute most of the risk of cancer fatality to the offsite population, by site and alternative.
- Tables D.3.2–46 through D.3.2–60 present programwide risks associated with disposal of LLW under each alternative, by site.

***Table D.3.2–2. Summary of Programwide Risks Associated With Treatment of LLW: Risks to Total Populations, by Alternative***

| Alternative | Offsite Population | | Noninvolved Worker Population | | WM Workers | | |
|---|---|---|---|---|---|---|---|
| | CF | CI | CF | CI | CF | CI | C&OF |
| No Action | 2.0E–03 | 7.0E–03 | 6.0E–05 | 2.0E–04 | 1.2 | 4.2 | 2.5 |
| **Minimum Treatment Alternatives** | | | | | | | |
| Decentralized | 2.9E–02 | 9.8E–02 | 1.9E–04 | 6.4E–04 | 8.3E–01 | 2.9 | 1.9 |
| Regionalized 1 | 2.9E–02 | 9.8E–02 | 1.9E–04 | 6.4E–04 | 8.1E–01 | 2.8 | 1.9 |
| Regionalized 3 | 2.9E–02 | 9.8E–02 | 1.9E–04 | 6.4E–04 | 8.1E–01 | 2.8 | 2.0 |
| Regionalized 6 | 2.9E–02 | 9.8E–02 | 1.9E–04 | 6.4E–04 | 8.6E–01 | 3.0 | 2.2 |
| Regionalized 7 | 2.9E–02 | 9.8E–02 | 1.9E–04 | 6.4E–04 | 8.6E–01 | 3.0 | 2.2 |
| Centralized 1 | 2.9E–02 | 9.8E–02 | 1.9E–04 | 6.4E–04 | 8.6E–01 | 3.0 | 2.2 |
| Centralized 2 | 2.9E–02 | 9.8E–02 | 1.9E–04 | 6.4E–04 | 8.6E–01 | 3.0 | 2.2 |
| **Volume Reduction Alternatives** | | | | | | | |
| Regionalized 2 | 6.4E–01 | 2.2 | 6.6E–03 | 2.2E–02 | 1.3 | 4.5 | 3.9 |
| Regionalized 4 | 9.7E–02 | 3.3E–01 | 1.9E–03 | 6.5E–03 | 1.5 | 5.0 | 3.9 |
| Centralized 3 | 1.0E–01 | 3.4E–01 | 2.0E–03 | 7.0E–03 | 1.4 | 5.0 | 3.9 |
| Centralized 4 | 1.0E–01 | 3.4E–01 | 2.0E–03 | 7.0E–03 | 1.4 | 5.0 | 3.9 |
| Regionalized 5 | 3.7E–01 | 1.3 | 5.1E–03 | 1.7E–03 | 1.7 | 5.8 | 3.4 |
| Centralized 5 | 9.8E–02 | 3.33E–01 | 1.1E–03 | 3.7E–03 | 2.3 | 7.7 | 4.1 |

Notes: CF = cancer fatality associated with radionuclide exposure; CI = cancer incidence associated with exposure to radionuclides; C&OF = fatalities due to the physical hazards of constructing and operating waste management facilities.

***Table D.3.2–3. Summary of Programwide Risks Associated With Disposal of LLW: Risks to Hypothetical Farm Family and Waste Management Workers, by Alternative***

| Alternative | MEL of Farm Family | | All (143) Lifetimes of Farm Family | | WM Workers | | |
|---|---|---|---|---|---|---|---|
| | CF | CI | CF | CI | CF | CI | C&OF |
| No Action | 5.7E–03 | 2.0E–02 | 7.6E–02 | 2.6E–01 | 3.2 | 11 | 3.4 |
| **Decentralized Disposal** | | | | | | | |
| Decentralized | 6.7E–02 | 2.3E–01 | 1.3 | 4.5 | 2.6 | 9 | 5.5 |
| **Regionalized Disposal** | | | | | | | |
| Regionalized 1 | 1.5E–03 | 5.1E–03 | 2.2E–02 | 7.4E–02 | 2.5 | 8.6 | 5.4 |
| Regionalized 2 | 5.2E–03 | 1.8E–02 | 7.2E–02 | 2.5E–01 | 2.0 | 6.9 | 4.1 |
| Regionalized 3 | 1.1E–03 | 3.9E–03 | 1.6E–02 | 5.3E–02 | 2.8 | 9.6 | 4.9 |
| Regionalized 4 | 1.4E–02 | 4.7E–02 | 1.9E–01 | 6.2E–01 | 2.1 | 7.4 | 3.8 |
| Regionalized 5 | 1.4E–02 | 4.7E–02 | 1.9E–01 | 6.2E–01 | 2.1 | 7.4 | 3.8 |
| Regionalized 6 | 1.6E–02 | 5.6E–02 | 2.2E–01 | 7.3E–01 | 1.8 | 6.2 | 6.4 |
| Regionalized 7 | 1.7E–04 | 5.9E–04 | 1.8E–04 | 6.3E–03 | 1.4 | 4.9 | 6.0 |
| **Centralized Disposal** | | | | | | | |
| Centralized 1 | 4.8E–03 | 1.6E–02 | 6.4E–02 | 2.2E–01 | 2.8 | 9.7 | 1.4 |
| Centralized 2 | 0.00 | 0.00 | 0.00 | 0.00 | 2.2 | 7.7 | 6.1E–01 |
| Centralized 3 | 9.2E–03 | 3.1E–02 | 1.2E–01 | 4.2E–01 | 1.8 | 6.2 | 8.8E–01 |
| Centralized 4 | 0.00 | 0.00 | 0.00 | 0.00 | 1.6 | 5.5 | 3.9E–01 |
| Centralized 5 | 9.2E–03 | 3.1E–02 | 1.2E–01 | 4.2E–01 | 1.8 | 6.2 | 8.8E–01 |

Notes: CF = risk of cancer fatality associated with exposure to radionuclides; CI = risk of cancer incidence associated with exposure to radionuclides; C&OF = estimated construction and operational fatalities from physical hazards.

*Table D.3.2–4. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of LLW, by Alternative*

| Alternative | Offsite Population | Noninvolved Worker Population | WM Workers |
|---|---|---|---|
| No Action | 44,304,014 | 123,959 | 17,433 |
| Decentralized | 44,304,014 | 123,959 | 10,191 |
| Regionalized 1 | 44,304,014 | 123,959 | 10,389 |
| Regionalized 3 | 44,304,014 | 123,959 | 10,737 |
| Regionalized 6 | 44,304,014 | 123,959 | 11,833 |
| Regionalized 7 | 44,304,014 | 123,959 | 12,055 |
| Centralized 1 | 44,304,014 | 123,959 | 11,855 |
| Centralized 2 | 44,304,014 | 123,959 | 12,077 |
| Regionalized 2 | 47,068,603 | 126,415 | 21,443 |
| Regionalized 4 | 44,304,014 | 123,959 | 21,823 |
| Centralized 3 | 44,304,014 | 123,959 | 21,972 |
| Centralized 4 | 44,304,014 | 123,959 | 21,972 |
| Regionalized 5 | 44,304,014 | 123,959 | 19,989 |
| Centralized 5 | 44,304,014 | 123,959 | 20,762 |

*Table D.3.2–5. Summary of Programwide Risks Associated With Treatment of LLW: Risks to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative*

| Alternative | Offsite MEI | | Noninvolved Worker MEI | |
|---|---|---|---|---|
| | CF | CI | CF | CI |
| No Action | 2.0E–08 | 6.9E–08 | 2.9E–08 | 9.7E–08 |
| Decentralized | 2.9E–07 | 9.7E–07 | 4.7E–08 | 1.6E–07 |
| Regionalized 1 | 2.9E–07 | 9.7E–07 | 4.7E–08 | 1.6E–07 |
| Regionalized 3 | 2.9E–07 | 9.7E–07 | 4.7E–08 | 1.6E–07 |
| Regionalized 6 | 2.9E–07 | 9.7E–07 | 4.7E–08 | 1.6E–07 |
| Regionalized 7 | 2.9E–07 | 9.7E–07 | 4.7E–08 | 1.6E–07 |
| Centralized 1 | 2.9E–07 | 9.7E–07 | 4.7E–08 | 1.6E–07 |
| Centralized 2 | 2.9E–07 | 9.7E–07 | 4.7E–08 | 1.6E–07 |
| Regionalized 2 | 6.3E–06 | 2.1E–05 | 1.8E–06 | 6.2E–06 |
| Regionalized 4 | 2.3E–06 | 7.9E–06 | 8.5E–07 | 2.9E–06 |
| Centralized 3 | 2.3E–06 | 7.9E–06 | 6.3E–07 | 2.0E–06 |
| Centralized 4 | 2.3E–06 | 7.9E–06 | 6.3E–07 | 2.0E–06 |
| Regionalized 5 | 9.3E–06 | 3.2E–05 | 4.1E–06 | 1.4E–05 |
| Centralized 5 | 1.5E–06 | 5.2E–06 | 1.7E–06 | 5.8E–06 |

Notes: MEI = maximally exposed individual; CF = risk of cancer fatality associated with exposure to radionuclides; CI = risk of cancer incidence associated with exposure to radionuclides.

***Table D.3.2–6. Radionuclide Contributing the Highest Risk of Cancer Fatality to the Offsite Population for LLW Treatment, by Alternative and Site***

| Alt. | Site | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ANL-E | BNL | FEMP | Hanford | INEL | KCP | KAPL-K | LBL | LLNL | LANL | Mound |
| No Action | Pu-238[a] 7.0E-07[b] | Pu-238 6.5E-07 | | Pu-238 2.3E-07 | Co-60 1.3E-06 | U-238 5.5E-10 | Co-60 5.3E-04 | H-3 7.6E-04 | U-238 2.4E-07 | Pu-238 1.1E-04 | Pu-238 4.3E-08 |
| Dec. | Pu-238 7.6E-07 | Pu-238 8.5E-09 | | Pu-238 1.5E-06 | Co-60 7.6E-07 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | H-3 1.0E-01 | Pu-238 1.2E-04 | Pu-238 4.7E-08 |
| Reg. 1 | Pu-238 7.6E-07 | Pu-238 7.0E-07 | | Pu-238 1.5E-06 | Co-60 7.6E-07 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | H-3 1.0E-01 | Pu-238 1.2E-04 | Pu-238 4.7E-08 |
| Reg. 3 | Pu-238 7.6E-07 | Pu-238 7.0E-07 | | Pu-238 1.5E-06 | Co-60 7.6E-07 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | H-3 1.0E-01 | Pu-238 1.2E-04 | Pu-238 4.7E-08 |
| Reg. 6 | Pu-238 7.6E-07 | Pu-238 7.0E-07 | | Pu-238 1.5E-06 | Co-60 1.2E-06 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | H-3 1.0E-01 | Pu-238 1.2E-04 | Pu-238 4.7E-08 |
| Reg. 7 | Pu-238 7.6E-07 | Pu-238 7.0E-07 | | Pu-238 2.2E-06 | Co-60 1.2E-06 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | H-3 1.0E-01 | Pu-238 1.2E-04 | Pu-238 4.7E-08 |
| Cen. 1 | Pu-238 7.6E-07 | Pu-238 7.0E-07 | | Pu-238 1.5E-06 | Co-60 1.2E-06 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | H-3 1.0E-01 | Pu-238 1.2E-04 | Pu-238 4.7E-08 |
| Cen. 2 | Pu-238 7.6E-07 | Pu-238 7.0E-07 | | Pu-238 2.2E-06 | Co-60 1.2E-06 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | H-3 1.0E-01 | Pu-238 1.2E-04 | Pu-238 4.7E-08 |
| Reg. 2 | Pu-238 7.6E-07 | Pu-238 7.0E-07 | H-3 2.0E-01 | Pu-238 1.9E-06 | Co-60 1.3E-06 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | H-3 3.8E-01 | U-238 1.0E-01 | Pu-238 4.7E-08 |
| Reg. 4 | Pu-238 7.6E-07 | Pu-238 7.0E-07 | | H-3 5.0E-02 | Co-60 1.3E-06 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | | U-238 1.0E-01 | Pu-238 4.7E-08 |
| Cen. 3 Cen. 4 | Pu-238 7.6E-07 | Pu-238 7.0E-07 | | H-3 5.0E-02 | Co-60 1.3E-06 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | | U-238 1.0E-01 | Pu-238 4.7E-08 |
| Reg. 5 | Pu-238 7.6E-07 | Pu-238 7.0E-07 | | H-3 5.0E-02 | U-238 3.4E-04 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | | Pu-238 1.2E-04 | Pu-238 4.7E-08 |
| Cen. 5 | Pu-238 7.6E-07 | Pu-238 7.0E-07 | | H-3 7.0E-02 | Co-60 7.6E-07 | U-238 5.7E-10 | Co-60 5.2E-04 | H-3 2.0E-02 | | Pu-238 1.2E-04 | Pu-238 4.7E-08 |

| Alt. | NTS | K-25 | ORNL | Y-12 | PGDP | Pantex | Pinellas | PORTS | RFETS | SNL/NM | SRS | WVDP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action | Pu-238 2.4E-12 | U-238 5.5E-08 | Pu-238 2.7E-06 | U-238 1.2E-08 | U-238 1.8E-08 | H-3 9.0E-07 | H-3 1.8E-08 | U-238 1.6E-09 | Pu-238 4.9E-08 | U-238 8.8E-07 | H-3 4.1E-04 | Pu-238 2.1E-06 |
| Dec. | Pu-238 2.6E-12 | U-238 1.3E-07 | Pu-238 2.9E-06 | U-238 2.5E-08 | U-238 2.8E-07 | H-3 4.4E-07 | H-3 1.8E-08 | U-238 2.8E-10 | Pu-238 1.4E-07 | U-238 8.9E-07 | H-3 6.2E-06 | Pu-238 7.0E-07 |
| Reg. 1 | Pu-238 2.6E-12 | U-238 1.3E-07 | Pu-238 2.9E-06 | U-238 2.5E-08 | U-238 2.8E-07 | H-3 4.4E-07 | H-3 1.8E-08 | U-238 2.8E-10 | Pu-238 1.4E-07 | U-238 9.1E-07 | H-3 6.2E-06 | Pu-238 1.2E-06 |
| Reg. 3 | Pu-238 2.6E-12 | U-238 1.3E-07 | Pu-238 2.9E-06 | U-238 2.5E-08 | U-238 1.8E-08 | H-3 4.4E-07 | H-3 1.8E-08 | U-238 1.6E-09 | Pu-238 1.6E-07 | U-238 9.1E-07 | H-3 6.2E-06 | Pu-238 1.2E-06 |
| Reg. 6 | Pu-238 3.0E-12 | U-238 3.0E-07 | U-238 3.5E-06 | U-238 3.7E-08 | U-238 1.8E-08 | H-3 4.4E-07 | H-3 1.8E-08 | U-238 1.6E-09 | Pu-238 1.6E-07 | U-238 9.1E-07 | H-3 6.2E-06 | Pu-238 1.2E-06 |
| Reg. 7 | Pu-238 2.6E-12 | U-238 3.0E-07 | U-238 3.5E-06 | U-238 3.7E-08 | U-238 1.8E-08 | H-3 4.4E-07 | H-3 1.8E-08 | U-238 1.6E-09 | Pu-238 1.6E-07 | U-238 9.1E-07 | H-3 6.2E-06 | Pu-238 1.2E-06 |
| Cen. 1 | Pu-238 3.0E-12 | U-238 3.0E-07 | U-238 3.5E-06 | U-238 3.7E-08 | U-238 1.8E-08 | H-3 4.4E-07 | H-3 1.8E-08 | U-238 1.6E-09 | Pu-238 1.6E-07 | U-238 9.1E-07 | H-3 6.2E-06 | Pu-238 1.2E-06 |
| Cen. 2 | Pu-238 2.6E-12 | U-238 3.0E-07 | U-238 3.5E-06 | U-238 3.7E-08 | U-238 1.8E-08 | H-3 4.4E-07 | H-3 1.8E-08 | U-238 1.6E-09 | Pu-238 1.6E-07 | U-238 9.1E-07 | H-3 6.2E-06 | Pu-238 1.2E-06 |
| Reg. 2 | Pu-238 3.0E-12 | U-238 5.5E-08 | U-238 6.5E-05 | U-238 1.3E-08 | U-238 1.6E-06 | H-3 4.4E-07 | H-3 1.8E-08 | Co-60 5.8E-05 | Pu-238 7.4E-05 | U-238 9.1E-07 | H-3 4.1E-04 | Pu-238 1.2E-06 |
| Reg. 4 | Pu-238 3.0E-12 | U-238 5.5E-08 | U-238 6.5E-05 | U-238 1.3E-08 | U-238 1.8E-08 | H-3 4.4E-07 | H-3 1.8E-08 | H-3 2.0E-01 | Pu-238 7.4E-05 | U-238 9.1E-07 | H-3 4.1E-04 | Pu-238 1.2E-06 |
| Cen. 3 Cen. 4 | Pu-238 3.0E-12 | U-238 7.5E-08 | U-238 6.5E-05 | U-238 1.6E-08 | U-238 1.8E-08 | H-3 4.4E-07 | H-3 1.8E-08 | H-3 2.0E-01 | Pu-238 7.4E-05 | U-238 9.1E-07 | H-3 4.1E-04 | Pu-238 1.2E-06 |
| Reg. 5 | Pu-238 3.0E-12 | U-238 5.5E-08 | H-3 3.0E-01 | U-238 1.3E-08 | U-238 1.8E-08 | H-3 4.4E-07 | H-3 1.8E-08 | U-238 1.6E-09 | Pu-238 1.6E-07 | U-238 9.1E-07 | H-3 4.1E-04 | Pu-238 1.2E-06 |
| Cen. 5 | Pu-238 3.0E-12 | U-238 3.0E-07 | U-238 3.5E-06 | U-238 3.7E-08 | U-238 1.8E-08 | H-3 4.4E-07 | H-3 1.8E-08 | U-238 1.6E-09 | Pu-238 1.6E-07 | U-238 9.1E-07 | Co-60 5.0E-6 | Pu-238 1.2E-06 |

Notes: Alt. = Alternative; Dec. = Decentralized; Reg. = Regionalized; and Cen. = Centralized.
[a] Radionuclide contributing most risk.
[b] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this site.

***Table D.3.2–7. Programwide Risks Associated With Treatment of LLW Under the No Action Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 1.0E–01 | |
| | Cancer Fatalities | 6.0E–05 | |
| | Cancer incidence | 2.0E–04 | |
| | Genetic effects | 1.0E–05 | |
| Noninvolved worker MEI | Dose (rem) | 5.7E–05 | |
| | Cancer Fatalities | 2.9E–08 | |
| | Cancer incidence | 9.7E–08 | |
| | Genetic effects | 5.7E–09 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 5.0E+00 | |
| | Cancer Fatalities | 2.0E–03 | |
| | Cancer incidence | 7.0E–03 | |
| | Genetic effects | 5.0E–04 | |
| Offsite MEI | Dose (rem) | 4.1E–05 | |
| | Cancer Fatalities | 2.0E–08 | |
| | Cancer incidence | 6.9E–08 | |
| | Genetic effects | 4.1E–09 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 2.9E+03 | |
| | Cancer Fatalities | 1.2E+00 | |
| | Cancer incidence | 4.2 | |
| | Genetic effects | 1.8E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 8.2E–01 |
| | Construction injuries | | 3.3E+02 |
| | Operation fatalities | | 1.7 |
| | Operation injuries | | 1.3E+03 |

***Table D.3.2–8. Programwide Risks Associated With Treatment of LLW Under the Decentralized Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 3.7E–01 | |
| | Cancer fatalities | 1.9E–04 | |
| | Cancer incidence | 6.4E–04 | |
| | Genetic effects | 3.7E–05 | |
| Noninvolved worker MEI | Dose (rem) | 9.5E–05 | |
| | Cancer fatalities | 4.7E–08 | |
| | Cancer incidence | 1.6E–07 | |
| | Genetic effects | 9.5E–09 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 5.8E+01 | |
| | Cancer fatalities | 2.9E–02 | |
| | Cancer incidence | 9.8E–02 | |
| | Genetic effects | 5.8E–03 | |
| Offsite MEI | Dose (rem) | 5.7E–04 | |
| | Cancer fatalities | 2.9E–07 | |
| | Cancer incidence | 9.7E–07 | |
| | Genetic effects | 5.7E–08 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 2.1E+03 | |
| | Cancer fatalities | 8.3E–01 | |
| | Cancer incidence | 2.9 | |
| | Genetic effects | 1.2E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 9.2E–01 |
| | Construction injuries | | 3.7E+02 |
| | Operation fatalities | | 9.9E–01 |
| | Operation injuries | | 7.6E+02 |

***Table D.3.2–9. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 1, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 3.7E–01 | |
| | Cancer fatalities | 1.9E–04 | |
| | Cancer incidence | 6.4E–04 | |
| | Genetic effects | 3.7E–05 | |
| Noninvolved worker MEI | Dose (rem) | 9.4E–05 | |
| | Cancer fatalities | 4.7E–08 | |
| | Cancer incidence | 1.6E–07 | |
| | Genetic effects | 9.4E–09 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 5.8E+01 | |
| | Cancer fatalities | 2.9E–02 | |
| | Cancer incidence | 9.8E–02 | |
| | Genetic effects | 5.8E–03 | |
| Offsite MEI | Dose (rem) | 5.7E–04 | |
| | Cancer fatalities | 2.9E–07 | |
| | Cancer incidence | 9.7E–07 | |
| | Genetic effects | 5.7E–08 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 2.0E+03 | |
| | Cancer fatalities | 8.1E–01 | |
| | Cancer incidence | 2.8 | |
| | Genetic effects | 1.2E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 9.3E–01 |
| | Construction injuries | | 3.8E+02 |
| | Operation fatalities | | 1.0 |
| | Operation injuries | | 7.6E+02 |

***Table D.3.2–10. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 3, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 3.7E–01 | |
| | Cancer fatalities | 1.9E–04 | |
| | Cancer incidence | 6.4E–04 | |
| | Genetic effects | 3.7E–05 | |
| Noninvolved worker MEI | Dose (rem) | 9.4E–05 | |
| | Cancer fatalities | 4.7E–08 | |
| | Cancer incidence | 1.6E–07 | |
| | Genetic effects | 9.4E–09 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 5.8E+01 | |
| | Cancer fatalities | 2.9E–02 | |
| | Cancer incidence | 9.8E–02 | |
| | Genetic effects | 5.8E–03 | |
| Offsite MEI | Dose (rem) | 5.7E–04 | |
| | Cancer fatalities | 2.9E–07 | |
| | Cancer incidence | 9.7E–07 | |
| | Genetic effects | 5.7E–08 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 2.0E+03 | |
| | Cancer fatalities | 8.1E–01 | |
| | Cancer incidence | 2.8 | |
| | Genetic effects | 1.2E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 9.4E–01 |
| | Construction injuries | | 3.9E+02 |
| | Operation fatalities | | 1.1 |
| | Operation injuries | | 8.4E+02 |

***Table D.3.2-11. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 6, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 3.7E-01 | |
| | Cancer fatalities | 1.9E-04 | |
| | Cancer incidence | 6.4E-04 | |
| | Genetic effects | 3.7E-05 | |
| Noninvolved worker MEI | Dose (rem) | 9.5E-05 | |
| | Cancer fatalities | 4.7E-08 | |
| | Cancer incidence | 1.6E-07 | |
| | Genetic effects | 9.5E-09 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 5.8E+01 | |
| | Cancer fatalities | 2.9E-02 | |
| | Cancer incidence | 9.8E-02 | |
| | Genetic effects | 5.8E-03 | |
| Offsite MEI | Dose (rem) | 5.7E-04 | |
| | Cancer fatalities | 2.9E-07 | |
| | Cancer incidence | 9.7E-07 | |
| | Genetic effects | 5.7E-08 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 2.1E+03 | |
| | Cancer fatalities | 8.6E-01 | |
| | Cancer incidence | 3.0 | |
| | Genetic effects | 1.3E-01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.1 |
| | Construction injuries | | 4.3E+02 |
| | Operation fatalities | | 1.1 |
| | Operation injuries | | 8.8E+02 |

***Table D.3.2–12. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 7, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 3.7E–01 | |
| | Cancer fatalities | 1.9E–04 | |
| | Cancer incidence | 6.4E–04 | |
| | Genetic effects | 3.7E–05 | |
| Noninvolved worker MEI | Dose (rem) | 9.5E–05 | |
| | Cancer fatalities | 4.7E–08 | |
| | Cancer incidence | 1.6E–07 | |
| | Genetic effects | 9.5E–09 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 5.8E+01 | |
| | Cancer fatalities | 2.9E–02 | |
| | Cancer incidence | 9.8E–02 | |
| | Genetic effects | 5.8E–03 | |
| Offsite MEI | Dose (rem) | 5.7E–04 | |
| | Cancer fatalities | 2.9E–07 | |
| | Cancer incidence | 9.7E–07 | |
| | Genetic effects | 5.7E–08 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 2.1E+03 | |
| | Cancer fatalities | 8.6E–01 | |
| | Cancer incidence | 3.0 | |
| | Genetic effects | 1.3E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.1 |
| | Construction injuries | | 4.5E+02 |
| | Operation fatalities | | 1.1 |
| | Operation injuries | | 8.8E+02 |

***Table D.3.2–13. Programwide Risks Associated With Treatment of LLW Under the Centralized Alternative 1, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 3.7E–01 | |
| | Cancer fatalities | 1.9E–04 | |
| | Cancer incidence | 6.4E–04 | |
| | Genetic effects | 3.7E–05 | |
| Noninvolved worker MEI | Dose (rem) | 9.5E–05 | |
| | Cancer fatalities | 4.7E–08 | |
| | Cancer incidence | 1.6E–07 | |
| | Genetic effects | 9.5E–09 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 5.8E+01 | |
| | Cancer fatalities | 2.9E–02 | |
| | Cancer incidence | 9.8E–02 | |
| | Genetic effects | 5.8E–03 | |
| Offsite MEI | Dose (rem) | 5.7E–04 | |
| | Cancer fatalities | 2.9E–07 | |
| | Cancer incidence | 9.7E–07 | |
| | Genetic effects | 5.7E–08 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 2.1E+03 | |
| | Cancer fatalities | 8.6E–01 | |
| | Cancer incidence | 3 | |
| | Genetic effects | 1.3E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.1 |
| | Construction injuries | | 4.3E+02 |
| | Operation fatalities | | 1.1 |
| | Operation injuries | | 8.8E+02 |

***Table D.3.2–14. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 2, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 3.7E–01 | |
| | Cancer fatalities | 1.9E–04 | |
| | Cancer incidence | 6.4E–04 | |
| | Genetic effects | 3.7E–05 | |
| Noninvolved worker MEI | Dose (rem) | 9.5–05 | |
| | Cancer fatalities | 4.7E–08 | |
| | Cancer incidence | 1.6E–07 | |
| | Genetic effects | 9.5E–09 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 5.8E+01 | |
| | Cancer fatalities | 2.9E–02 | |
| | Cancer incidence | 9.8E–02 | |
| | Genetic effects | 5.8E–03 | |
| Offsite MEI | Dose (rem) | 5.7E–04 | |
| | Cancer fatalities | 2.9E–07 | |
| | Cancer incidence | 9.7E–07 | |
| | Genetic effects | 5.7E–08 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 2.1E+03 | |
| | Cancer fatalities | 8.6E–01 | |
| | Cancer incidence | 3.0 | |
| | Genetic effects | 1.3E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.1 |
| | Construction injuries | | 4.5E+02 |
| | Operation fatalities | | 1.1 |
| | Operation injuries | | 8.8E+02 |

***Table D.3.2–15. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 2, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 1.3E+01 | |
| | Cancer fatalities | 6.6E–03 | |
| | Cancer incidence | 2.2E–02 | |
| | Genetic effects | 1.3E–03 | |
| Noninvolved worker MEI | Dose (rem) | 3.6E–03 | |
| | Cancer fatalities | 1.8E–06 | |
| | Cancer incidence | 6.2E–06 | |
| | Genetic effects | 3.6E–07 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 1.3E+03 | |
| | Cancer fatalities | 6.4E–01 | |
| | Cancer incidence | 2.2 | |
| | Genetic effects | 1.3E–01 | |
| Offsite MEI | Dose (rem) | 1.3E–02 | |
| | Cancer fatalities | 6.3E–06 | |
| | Cancer incidence | 2.1E–05 | |
| | Genetic effects | 1.3E–06 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 3.2E+03 | |
| | Cancer fatalities | 1.3 | |
| | Cancer incidence | 4.5 | |
| | Genetic effects | 2.0E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.8 |
| | Construction injuries | | 7.3E+02 |
| | Operation fatalities | | 2.1 |
| | Operation injuries | | 1.6E+03 |

***Table D.3.2–16. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 4, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 3.8 | |
| | Cancer fatalities | 1.9E–03 | |
| | Cancer incidence | 6.5E–03 | |
| | Genetic effects | 3.8E–04 | |
| Noninvolved worker MEI | Dose (rem) | 1.7E–03 | |
| | Cancer fatalities | 8.5E–07 | |
| | Cancer incidence | 2.9E–06 | |
| | Genetic effects | 1.7E–07 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 2.0E+02 | |
| | Cancer fatalities | 9.7E–02 | |
| | Cancer incidence | 3.3E–01 | |
| | Genetic effects | 2.0E–02 | |
| Offsite MEI | Dose (rem) | 4.6E–03 | |
| | Cancer fatalities | 2.3E–06 | |
| | Cancer incidence | 7.9E–06 | |
| | Genetic effects | 4.6E–07 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 3.6E+03 | |
| | Cancer fatalities | 1.5 | |
| | Cancer incidence | 5.0 | |
| | Genetic effects | 2.1E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.8 |
| | Construction injuries | | 7.5E+02 |
| | Operation fatalities | | 2.1 |
| | Operation injuries | | 1.6E+03 |

***Table D.3.2–17. Programwide Risks Associated With Treatment of LLW Under Centralized Alternatives 3 and 4, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 4.1 | |
| | Cancer fatalities | 2.0E–03 | |
| | Cancer incidence | 7.0E–03 | |
| | Genetic effects | 4.1E–04 | |
| Noninvolved worker MEI | Dose (rem) | 1.2E–03 | |
| | Cancer fatalities | 6.3E–07 | |
| | Cancer incidence | 2.0E–06 | |
| | Genetic effects | 1.2E–07 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 2.0E+02 | |
| | Cancer fatalities | 1.0E–01 | |
| | Cancer incidence | 3.4E–01 | |
| | Genetic effects | 2.0E–02 | |
| Offsite MEI | Dose (rem) | 4.6E–03 | |
| | Cancer fatalities | 2.3E–06 | |
| | Cancer incidence | 7.9E–06 | |
| | Genetic effects | 4.6E–07 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 3.6E+03 | |
| | Cancer fatalities | 1.4 | |
| | Cancer incidence | 5.0 | |
| | Genetic effects | 2.2E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.8 |
| | Construction injuries | | 7.5E+02 |
| | Operation fatalities | | 2.1 |
| | Operation injuries | | 1.6E+03 |

***Table D.3.2–18. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 5, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 1.0E+01 | |
| | Cancer fatalities | 5.1E–03 | |
| | Cancer incidence | 1.7E–02 | |
| | Genetic effects | 1.0E–03 | |
| Noninvolved worker MEI | Dose (rem) | 8.3E–03 | |
| | Cancer fatalities | 4.1E–06 | |
| | Cancer incidence | 1.4E–05 | |
| | Genetic effects | 8.3E–07 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 7.5E+02 | |
| | Cancer fatalities | 3.7E–01 | |
| | Cancer incidence | 1.3 | |
| | Genetic effects | 7.5E–02 | |
| Offsite MEI | Dose (rem) | 1.9E–02 | |
| | Cancer fatalities | 9.3E–06 | |
| | Cancer incidence | 3.2E–05 | |
| | Genetic effects | 1.9E–06 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 4.2E+03 | |
| | Cancer fatalities | 1.7 | |
| | Cancer incidence | 5.8 | |
| | Genetic effects | 2.5E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.6 |
| | Construction injuries | | 6.3E+02 |
| | Operation fatalities | | 1.8 |
| | Operation injuries | | 1.3E+03 |

***Table D.3.2–19. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 5, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Noninvolved worker population | Dose (person-rem) | 2.2 | |
| | Cancer fatalities | 1.1E–03 | |
| | Cancer incidence | 3.7E–03 | |
| | Genetic effects | 2.2E–04 | |
| Noninvolved worker MEI | Dose (rem) | 3.4E–03 | |
| | Cancer fatalities | 1.7E–06 | |
| | Cancer incidence | 5.8E–06 | |
| | Genetic effects | 3.4E–07 | |
| | Hazard index | | |
| Offsite population | Dose (person-rem) | 2.0E+02 | |
| | Cancer fatalities | 9.8E–02 | |
| | Cancer incidence | 3.3E–01 | |
| | Genetic effects | 2.0E–02 | |
| Offsite MEI | Dose (rem) | 3.1E–03 | |
| | Cancer fatalities | 1.5E–06 | |
| | Cancer incidence | 5.2E–06 | |
| | Genetic effects | 3.1E–07 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 5.5E+03 | |
| | Cancer fatalities | 2.3 | |
| | Cancer incidence | 7.7 | |
| | Genetic effects | 3.2E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.9 |
| | Construction injuries | | 8.0E+02 |
| | Operation fatalities | | 2.2 |
| | Operation injuries | | 1.8E+03 |

***Table D.3.2–20. Programwide Risks Associated With Treatment of LLW Under the No Action Alternative, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| INEL | 153,061 / 2,169 | 1.4E–06 | 1.7E–10 | 6.1E–01 | 4.7E–06 | 5.8E–10 | 8.7E–01 |
| Hanford | 377,645 / 997 | 4.2E–07 | 8.6E–12 | 3.2E–01 | 1.4E–06 | 2.9E–11 | 5.4E–01 |
| KAPL-K | 1,290,172 / 925 | 5.3E–04 | 1.2E–08 | 1.7E–01 | 1.8E–03 | 4.0E–08 | 1.8E–02 |
| LBL | 5,856,829 / 236 | 7.6E–04 | 1.2E–08 | 5.1E–02 | 2.6E–03 | 4.1E–08 | 2.9E–02 |
| LANL | 159,152 / 920 | 1.9E–04 | 2.0E–08 | 3.3E–01 | 6.6E–04 | 6.9E–08 | 6.2E–01 |
| NTS | 14,266 / 78 | 1.3E–12 | 3.3E–16 | 5.4E–03 | 4.5E–12 | 1.1E–15 | 1.3E–03 |
| ORNL | 881,652 / 893 | 4.6E–06 | 1.4E–10 | 1.9E–01 | 1.6E–05 | 4.9E–10 | 3.9E–01 |
| SNL-NM | 610,714 / 277 | 1.7E–06 | 6.8E–11 | 5.1E–02 | 5.8E–06 | 2.3E–10 | 1.8E–03 |
| SRS | 620,618 / 3,032 | 5.9E–04 | 5.6E–09 | 8.5E–01 | 2.0E–03 | 1.9E–08 | 1.2 |
| KCP | 1,729,833 / 13 | 1.0E–09 | 4.6E–14 | 2.4E–03 | 3.4E–09 | 1.6E–13 | 1.3E–04 |
| LLNL | 6,324,234 / 426 | 3.5E–07 | 5.8E–12 | 7.0E–02 | 1.2E–06 | 2.0E–11 | 4.1E–03 |
| Mound | 3,032,983 / 710 | 9.4E–08 | 5.5E–12 | 1.4E–01 | 3.2E–07 | 1.9E–11 | 7.2E–03 |
| K-25 | 871,406 / 1,278 | 5.8E–08 | 1.3E–12 | 8.0E–02 | 2.0E–07 | 4.3E–12 | 2.3E–02 |
| Y-12 | 895,379 / 724 | 1.3E–08 | 4.9E–13 | 5.7E–02 | 4.5E–08 | 1.7E–12 | 9.7E–03 |
| PGDP | 500,502 / 654 | 2.0E–08 | 2.3E–12 | 1.2E–01 | 6.9E–08 | 7.6E–12 | 7.8E–03 |
| Pantex | 265,185 / 333 | 8.8E–07 | 7.5E–11 | 3.0E–02 | 3.0E–06 | 2.5E–10 | 3.4E–03 |
| Pinellas | 2,532,174 / 26 | 1.8E–08 | 3.8E–13 | 4.7E–03 | 6.0E–08 | 1.3E–12 | 2.4E–04 |
| PORTS | 639,602 / 1,450 | 1.7E–09 | 2.1E–13 | 2.5E–01 | 5.7E–09 | 7.2E–13 | 2.0E–02 |
| RFETS | 2,171,877 / 656 | 1.2E–07 | 1.7E–12 | 1.2E–01 | 4.1E–07 | 5.6E–12 | 6.5E–03 |
| ANL-E | 7,939,785 / 402 | 2.3E–06 | 1.3E–11 | 1.1E–01 | 8.0E–06 | 4.4E–11 | 1.5E–01 |
| BNL | 5,738,554 / 695 | 2.2E–06 | 2.9E–11 | 1.1E–01 | 7.4E–06 | 9.9E–11 | 2.1E–01 |
| WVDP | 1,698,391 / 539 | 3.5E–06 | 5.3E–11 | 5.7E–02 | 1.2E–05 | 1.8E–10 | 6.5E–02 |
| Total | | 2.0E–03 | 2.0E–08 | 3.7 | 7.0E–03 | 6.9E–08 | 4.2 |

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–21. Programwide Risks Associated With Treatment of LLW Under the Decentralized Alternative, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| ANL-E | 7,939,785 / 224 | 2.5E–06 | 1.4E–11 | 8.3E–02 | 8.5E–06 | 4.7E–11 | 1.1E–01 |
| Hanford | 377,645 / 577 | 2.7E–06 | 5.5E–11 | 2.2E–01 | 9.1E–06 | 1.9E–10 | 3.5E–01 |
| INEL | 153,061 / 677 | 8.0E–07 | 9.9E–11 | 3.2E–01 | 2.7E–06 | 3.4E–10 | 5.8E–01 |
| KAPL-K | 1,290,172 / 650 | 5.3E–04 | 1.2E–08 | 1.5E–01 | 1.8E–03 | 4.0E–08 | 2.0E–02 |
| LBL | 5,856,829 / 174 | 1.8E–02 | 2.9E–07 | 5.1E–02 | 6.2E–02 | 9.7E–07 | 2.7E–02 |
| LLNL | 6,324,234 / 191 | 1.0E–02 | 1.6E–07 | 5.0E–02 | 3.4E–02 | 5.5E–07 | 8.9E–03 |
| LANL | 159,152 / 653 | 2.1E–04 | 2.2E–08 | 2.8E–01 | 7.1E–04 | 7.5E–08 | 4.9E–01 |
| ORNL | 881,652 / 347 | 5.0E–06 | 1.56E–10 | 1.09E–01 | 1.71E–05 | 5.31E–10 | 2.13E–01 |
| SNL-NM | 610,714 / 187 | 1.8E–06 | 7.1E–11 | 6.5E–02 | 6.1E–06 | 2.4E–10 | 7.6E–02 |
| SRS | 620,618 / 1,986 | 1.9E–05 | 1.7E–10 | 6.6E–01 | 6.3E–05 | 5.9E–10 | 7.9E–01 |
| BNL | 5,738,554 / 273 | 9.66E–09 | 1.29E–13 | 5.8E–02 | 3.28E–08 | 4.38E–13 | 1.27E–01 |
| KCP | 1,729,833 / 11 | 1.1E–09 | 4.8E–14 | 2.6E–03 | 3.6E–09 | 1.6E–13 | 1.0E–04 |
| Mound | 3,032,983 / 435 | 1.0E–07 | 5.9E–12 | 1.1E–01 | 3.5E–07 | 2.0E–11 | 4.7E–03 |
| K-25 | 871,406 / 1,042 | 1.33E–07 | 2.9E–12 | 9.0E–02 | 4.53E–07 | 9.97E–12 | 1.87E–02 |
| Y-12 | 895,379 / 503 | 2.6E–08 | 9.7E–13 | 5.4E–02 | 8.9E–08 | 3.3E–12 | 7.1E–03 |
| PGDP | 500,502 / 501 | 3.2E–07 | 3.6E–11 | 1.1E–01 | 1.1E–06 | 1.2E–10 | 5.2E–03 |
| Pantex | 265,185 / 214 | 4.38E–07 | 3.73E–11 | 2.6E–02 | 1.5E–06 | 1.3E–10 | 2.7E–03 |
| Pinellas | 2,532,174 / 21 | 1.8E–08 | 3.8E–13 | 5.1E–03 | 6.0E–08 | 1.3E–12 | 2.0E–04 |
| PORTS | 639,602 / 730 | 2.4E–10 | 3.1E–14 | 1.5E–01 | 8.3E–10 | 1.1E–13 | 1.6E–02 |
| RFETS | 2,171,877 / 298 | 3.6E–07 | 4.9E–12 | 7.1E–02 | 1.2E–06 | 1.7E–11 | 4.0E–03 |
| NTS | 14,266 / 64 | 1.43E–12 | 3.62E–16 | 6.5E–03 | 4.86E–12 | 1.23E–15 | 1.03E–03 |
| WVDP | 1,698,391 / 433 | 1.24E–06 | 1.86E–11 | 6.2E–02 | 4.2E–06 | 6.3E–11 | 4.5E–02 |
| Total | | 2.9E–02 | 2.9E–07 | 2.7 | 9.9E–02 | 9.7E–07 | 2.9 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–22. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 1, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Hanford | 377,645 / 577 | 2.7E-06 | 5.5E-11 | 2.2E-01 | 9.1E-06 | 1.9E-10 | 3.5E-01 |
| INEL | 153,061 / 677 | 8.0E-07 | 9.9E-11 | 3.2E-01 | 2.7E-06 | 3.4E-10 | 5.8E-01 |
| KAPL-K | 1,290,172 / 650 | 5.3E-04 | 1.2E-08 | 1.5E-01 | 1.8E-03 | 4.0E-08 | 2.0E-02 |
| LBL | 5,856,829 / 174 | 1.8E-02 | 2.9E-07 | 5.1E-02 | 6.2E-02 | 9.7E-07 | 2.7E-02 |
| LLNL | 6,324,234 / 191 | 1.0E-02 | 1.6E-07 | 5.0E-02 | 3.4E-02 | 5.5E-07 | 8.9E-03 |
| LANL | 159,152 / 653 | 2.1E-04 | 2.2E-08 | 2.8E-01 | 7.1E-04 | 7.5E-08 | 4.9E-01 |
| ORNL | 881,652 / 347 | 5.0E-06 | 1.6E-10 | 1.1E-01 | 1.7E-05 | 5.3E-10 | 2.1E-01 |
| PORTS | 639,602 / 730 | 2.4E-10 | 3.1E-14 | 1.5E-01 | 8.3E-10 | 1.1E-13 | 1.6E-02 |
| SNL-NM | 610,714 / 210 | 1.8E-06 | 7.2E-11 | 5.1E-02 | 6.2E-06 | 2.4E-10 | 1.5E-03 |
| SRS | 620,618 / 1,986 | 1.9E-05 | 1.7E-10 | 6.6E-01 | 6.3E-05 | 5.9E-10 | 7.9E-01 |
| ANL-E | 7,939,785 / 224 | 2.5E-06 | 1.4E-11 | 8.3E-02 | 8.5E-06 | 4.7E-11 | 1.1E-01 |
| KCP | 1,729,833 / 11 | 1.1E-09 | 4.8E-14 | 2.6E-03 | 3.6E-09 | 1.6E-13 | 1.0E-04 |
| Mound | 3,032,983 / 435 | 1.0E-07 | 5.9E-12 | 1.1E-01 | 3.5E-07 | 2.0E-11 | 4.7E-03 |
| K-25 | 871,406 / 1,042 | 1.3E-07 | 2.9E-12 | 9.0E-02 | 4.5E-07 | 1.0E-11 | 1.9E-02 |
| Y-12 | 895,379 / 503 | 2.6E-08 | 9.7E-13 | 5.4E-02 | 8.9E-08 | 3.3E-12 | 7.1E-03 |
| PGDP | 500,502 / 501 | 3.2E-07 | 3.6E-11 | 1.1E-01 | 1.1E-06 | 1.2E-10 | 5.2E-03 |
| Pantex | 265,185 / 214 | 4.4E-07 | 3.7E-11 | 2.6E-02 | 1.5E-06 | 1.3E-10 | 2.7E-03 |
| Pinellas | 2,532,174 / 21 | 1.8E-08 | 3.8E-13 | 5.1E-03 | 6.0E-08 | 1.3E-12 | 2.0E-04 |
| RFETS | 2,171,877 / 298 | 3.6E-07 | 4.9E-12 | 7.1E-02 | 1.2E-06 | 1.7E-11 | 4.0E-03 |
| NTS | 14,266 / 64 | 1.4E-12 | 3.6E-16 | 6.5E-03 | 4.9E-12 | 1.2E-15 | 1.0E-03 |
| BNL | 5,738,554 / 417 | 2.3E-06 | 3.1E-11 | 8.3E-02 | 7.9E-06 | 1.0E-10 | 1.4E-01 |
| WVDP | 1,698,391 / 464 | 2.1E-06 | 3.1E-11 | 6.6E-02 | 7.0E-06 | 1.0E-10 | 4.5E-02 |
| Total | | 2.9E-02 | 2.9E-07 | 2.8 | 9.8E-02 | 9.7E-07 | 2.8 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–23. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 3, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Hanford | 377,645 / 577 | 2.7E–06 | 5.5E–11 | 2.2E–01 | 9.1E–06 | 1.9E–10 | 3.5E–01 |
| INEL | 153,061 / 677 | 8.0E–07 | 9.9E–11 | 3.2E–01 | 2.7E–06 | 3.4E–10 | 5.8E–01 |
| KAPL-K | 1,290,172 / 650 | 5.3E–04 | 1.2E–08 | 1.5E–01 | 1.8E–03 | 4.0E–08 | 2.0E–02 |
| LBL | 5,856,829 / 174 | 1.8E–02 | 2.9E–07 | 5.1E–02 | 6.2E–02 | 9.7E–07 | 2.7E–02 |
| LANL | 159,152 / 653 | 2.1E–04 | 2.2E–08 | 2.8E–01 | 7.1E–04 | 7.5E–08 | 4.9E–01 |
| NTS | 14,266 / 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ORNL | 881,652 / 266 | 5.0E–06 | 1.6E–10 | 8.9E–02 | 1.7E–05 | 5.3E–10 | 2.1E–01 |
| SNL-NM | 610,714 / 210 | 1.8E–06 | 7.2E–11 | 5.1E–02 | 6.2E–06 | 2.4E–10 | 1.5E–03 |
| SRS | 620,618 / 1,986 | 1.9E–05 | 1.7E–10 | 6.6E–01 | 6.3E–05 | 5.9E–10 | 7.9E–01 |
| ANL-E | 7,939,785 / 224 | 2.5E–06 | 1.4E–11 | 8.3E–02 | 8.5E–06 | 4.7E–11 | 1.1E–01 |
| KCP | 1,729,833 / 11 | 1.1E–09 | 4.8E–14 | 2.6E–03 | 3.6E–09 | 1.6E–13 | 1.0E–04 |
| LLNL | 6,324,234 / 227 | 1.0E–02 | 1.6E–07 | 5.9E–02 | 3.4E–02 | 5.5E–07 | 8.9E–03 |
| Mound | 3,032,983 / 435 | 1.0E–07 | 5.9E–12 | 1.1E–01 | 3.5E–07 | 2.0E–11 | 4.7E–03 |
| K-25 | 871,406 / 1,042 | 1.3E–07 | 2.9E–12 | 9.0E–02 | 4.5E–07 | 1.0E–11 | 1.9E–02 |
| Y-12 | 895,379 / 503 | 2.6E–08 | 9.7E–13 | 5.4E–02 | 8.9E–08 | 3.3E–12 | 7.1E–03 |
| PGDP | 500,502 / 503 | 2.1E–08 | 9.7E–13 | 5.4E–02 | 8.9E–08 | 3.3E–12 | 7.1E–03 |
| Pantex | 265,185 / 214 | 4.4E–07 | 3.7E–11 | 2.6E–02 | 1.5E–06 | 1.3E–10 | 2.7E–03 |
| Pinellas | 2,532,174 / 21 | 1.8E–08 | 3.8E–13 | 5.1E–03 | 6.0E–08 | 1.3E–12 | 2.0E–04 |
| PORTS | 639,602 / 1,075 | 1.8E–09 | 2.2E–13 | 2.3E–01 | 6.0E–09 | 7.5E–13 | 1.6E–02 |
| RFETS | 2,171,877 / 344 | 4.0E–07 | 5.4E–12 | 8.1E–02 | 1.4E–06 | 1.8E–11 | 4.0E–03 |
| NTS | 14,266 / 64 | 1.4E–12 | 3.6E–16 | 6.4E–03 | 4.9E–12 | 1.2E–15 | 1.0E–03 |
| BNL | 5,738,554 / 417 | 2.3E–06 | 3.1E–11 | 8.3E–02 | 7.9–06 | 1.0E–10 | 1.4E–01 |
| WVDP | 1,698,391 / 464 | 2.1E–06 | 3.1E–11 | 6.6E–02 | 7.0E–06 | 1.0E–10 | 4.5E–02 |
| Total | | 2.9E–02 | 2.9E–07 | 2.8 | 9.8E–02 | 9.7E–07 | 2.8 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–24. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 6, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Hanford | 377,645 / 577 | 2.7E-06 | 5.5E-11 | 2.2E-01 | 9.1E-06 | 1.9E-10 | 3.5E-01 |
| KAPL-K | 1,290,172 / 650 | 5.3E-04 | 1.2E-08 | 1.5E-01 | 1.8E-03 | 4.0E-08 | 2.0E-02 |
| LBL | 5,856,829 / 174 | 1.8E-02 | 2.9E-07 | 5.1E-02 | 6.2E-02 | 9.7E-07 | 2.7E-02 |
| LANL | 159,152 / 902 | 2.1E-04 | 2.2E-08 | 3.3E-01 | 7.1E-04 | 7.5E-08 | 4.9E-01 |
| ORNL | 881,652 / 382 | 1.2E-05 | 3.5E-10 | 1.2E-01 | 3.9E-05 | 1.2E-09 | 2.5E-01 |
| SNL-NM | 610,714 / 210 | 1.8E-06 | 7.2E-11 | 5.1E-02 | 6.2E-06 | 2.4E-10 | 1.5E-03 |
| SRS | 620,618 / 1,986 | 1.9E-05 | 1.7E-10 | 6.6E-01 | 6.3E-05 | 5.9E-10 | 7.9E-01 |
| INEL | 153,061 / 1,032 | 1.3E-06 | 1.6E-10 | 4.3E-01 | 4.4E-06 | 5.4E-10 | 7.2E-01 |
| ANL-E | 7,939,785 / 224 | 2.5E-06 | 1.4E-11 | 8.3E-02 | 8.5E-06 | 4.7E-11 | 1.1E-01 |
| KCP | 1,729,833 / 11 | 1.1E-09 | 4.8E-14 | 2.6E-03 | 3.6E-09 | 1.6E-13 | 1.0E-04 |
| LLNL | 6,324,234 / 227 | 1.0E-02 | 1.6E-07 | 5.9E-02 | 3.4E-02 | 5.5E-07 | 8.9E-03 |
| Mound | 3,032,983 / 435 | 1.0E-07 | 5.9E-12 | 1.1E-01 | 3.5E-07 | 2.0E-11 | 4.7E-03 |
| K-25 | 871,406 / 1,259 | 3.2E-07 | 7.0E-12 | 1.2E-01 | 1.1E-06 | 2.4E-11 | 1.9E-02 |
| Y-12 | 895,379 / 618 | 4.0E-08 | 1.5E-12 | 6.7E-02 | 1.4E-07 | 5.0E-12 | 7.1E-03 |
| PGDP | 500,502 / 503 | 2.1E-08 | 2.3E-12 | 1.1E-01 | 7.1E-08 | 8.0E-12 | 5.2E-03 |
| Pantex | 265,185 / 214 | 4.4E-07 | 3.7E-11 | 2.6E-02 | 1.5E-06 | 1.3E-10 | 2.7E-03 |
| Pinellas | 2,532,174 / 21 | 1.8E-08 | 3.8E-13 | 5.1E-03 | 6.0E-08 | 1.3E-12 | 2.0E-04 |
| PORTS | 639,602 / 1,075 | 1.8E-09 | 2.2E-13 | 2.3E-01 | 6.0E-09 | 7.5E-13 | 1.6E-02 |
| RFETS | 2,171,877 / 344 | 4.0E-07 | 5.4E-12 | 8.1E-02 | 1.4E-06 | 1.8E-11 | 4.0E-03 |
| NTS | 14,266 / 108 | 1.6E-12 | 4.1E-16 | 1.3E-02 | 5.5E-12 | 1.4E-15 | 1.0E-03 |
| BNL | 5,738,554 / 417 | 2.3E-06 | 3.1E-11 | 8.3E-02 | 7.9E-06 | 1.0E-10 | 1.4E-01 |
| WVDP | 1,698,391 / 464 | 2.1E-06 | 3.1E-11 | 6.6E-02 | 7.0E-06 | 1.0E-10 | 4.5E-02 |
| Total | | 2.9E-02 | 2.9E-07 | 3.1 | 9.8E-02 | 9.7E-07 | 3.0 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–25. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 7, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Hanford | 377,645 / 843 | 4.2E–06 | 8.5E–11 | 2.9E–01 | 1.4E–05 | 2.9E–10 | 3.6E–01 |
| KAPL-K | 1,290,172 / 650 | 5.3E–04 | 1.2E–08 | 1.5E–01 | 1.8E–03 | 4.0E–08 | 2.0E–02 |
| LBL | 5,856,829 / 174 | 1.8E–02 | 2.9E–07 | 5.1E–02 | 6.2E–02 | 9.7E–07 | 2.7E–02 |
| LANL | 159,152 / 902 | 2.1E–04 | 2.2E–08 | 3.3E–01 | 7.1E–04 | 7.5E–08 | 4.9E–01 |
| NTS | 14,266 / 64 | 1.4E–12 | 3.6E–16 | 6.5E–03 | 4.9E–12 | 1.2E–15 | 1.0E–03 |
| ORNL | 881,652 / 382 | 1.2E–05 | 3.5E–10 | 1.2E–01 | 3.9E–05 | 1.2E–09 | 2.5E–01 |
| SNL-NM | 610,714 / 210 | 1.8E–06 | 7.2E–11 | 5.1E–02 | 6.2E–06 | 2.4E–10 | 1.5E–03 |
| SRS | 620,618 / 1,986 | 1.9E–05 | 1.7E–10 | 6.6E–01 | 6.3E–05 | 5.9E–10 | 7.9E–01 |
| INEL | 153,061 / 1,032 | 1.3E–06 | 1.6E–10 | 4.3E–01 | 4.4E–06 | 5.4E–10 | 7.2E–01 |
| ANL-E | 7,939,785 / 224 | 2.5E–06 | 1.4E–11 | 8.3E–02 | 8.5E–06 | 4.7E–11 | 1.1E–01 |
| KCP | 1,729,833 / 11 | 1.1E–09 | 4.8E–14 | 2.6E–03 | 3.6E–09 | 1.6E–13 | 1.0E–04 |
| LLNL | 6,324,234 / 227 | 1.0E–02 | 1.6E–07 | 5.9E–02 | 3.4E–02 | 5.5E–07 | 8.9E–03 |
| Mound | 3,032,983 / 435 | 1.0E–07 | 5.9E–12 | 1.1E–01 | 3.5E–07 | 2.0E–11 | 4.7E–03 |
| K-25 | 871,406 / 1,259 | 3.2E–07 | 7.0E–12 | 1.2E–01 | 1.1E–06 | 2.4E–11 | 1.9E–02 |
| Y-12 | 895,379 / 618 | 4.0E–08 | 1.5E–12 | 6.7E–02 | 1.4E–07 | 5.0E–12 | 7.10E–03 |
| PGDP | 500,502 / 503 | 2.1E–08 | 2.3E–12 | 1.1E–01 | 7.1E–08 | 8.0E–12 | 5.2E–03 |
| Pantex | 265,185 / 214 | 4.4E–07 | 3.7E–11 | 2.6E–02 | 1.5E–06 | 1.3E–10 | 2.7E–03 |
| Pinellas | 2,532,174 / 21 | 1.8E–08 | 3.8E–13 | 5.1E–03 | 6.0E–08 | 1.3E–12 | 2.0E–04 |
| PORTS | 639,602 / 1,075 | 1.8E–09 | 2.2E–13 | 2.3E–01 | 6.0E–09 | 7.5E–13 | 1.6E–02 |
| RFETS | 2,171,877 / 344 | 4.0E–07 | 5.4E–12 | 8.1E–02 | 1.4E–06 | 1.8E–11 | 4.0E–03 |
| BNL | 5,738,554 / 417 | 2.3E–06 | 3.1E–11 | 8.3E–02 | 7.9E–06 | 1.0E–10 | 1.40E–01 |
| WVDP | 1,698,391 / 464 | 2.1E–06 | 3.1E–11 | 6.6E–02 | 7.0E–06 | 1.0E–10 | 4.5E–02 |
| Total | | 2.9E–02 | 2.9E–07 | 3.1 | 9.8E–02 | 9.7E–07 | 3.0 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–26. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 1, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Hanford | 377,645 / 577 | 2.7E–06 | 5.5E–11 | 2.2E–01 | 9.1E–06 | 1.9E–10 | 3.5E–01 |
| KAPL-K | 1,290,172 / 650 | 5.3E–04 | 1.2E–08 | 1.5E–01 | 1.8E–03 | 4.0E–08 | 2.0E–02 |
| LBL | 5,856,829 / 174 | 1.8E–02 | 2.9E–07 | 5.1E–02 | 6.2E–02 | 9.7E–07 | 2.7E–02 |
| LANL | 159,152 / 902 | 2.1E–04 | 2.2E–08 | 3.3E–01 | 7.1E–04 | 7.5E–08 | 4.9E–01 |
| ORNL | 881,652 / 382 | 1.2E–05 | 3.5E–10 | 1.2E–01 | 3.9E–05 | 1.2E–09 | 2.5E–01 |
| SNL-NM | 610,714 / 210 | 1.8E–06 | 7.2E–11 | 5.1E–02 | 6.2E–06 | 2.4E–10 | 1.5E–03 |
| SRS | 620,618 / 2,008 | 1.9E–05 | 1.8E–10 | 6.7E–01 | 6.3E–05 | 5.9E–10 | 8.0E–01 |
| INEL | 153,061 / 1,032 | 1.3E–06 | 1.6E–10 | 4.3E–01 | 4.4E–06 | 5.4E–10 | 7.2E–01 |
| KCP | 1,729,833 / 11 | 1.1E–09 | 4.8E–14 | 2.6E–03 | 3.6E–09 | 1.6E–13 | 1.0E–04 |
| LLNL | 6,324,234 / 227 | 1.0E–02 | 1.6E–07 | 5.9E–02 | 3.4E–02 | 5.5E–07 | 8.9E–03 |
| Mound | 3,032,983 / 435 | 1.0E–07 | 5.9E–12 | 1.1E–01 | 3.5E–07 | 2.0E–11 | 4.7E–03 |
| K-25 | 871,406 / 1,259 | 3.2E–07 | 7.0E–12 | 1.2E–01 | 1.1E–06 | 2.4E–11 | 1.9E–02 |
| Y-12 | 895,379 / 618 | 4.0E–08 | 1.5E–12 | 6.7E–02 | 1.4E–07 | 5.0E–12 | 7.10E–03 |
| PGDP | 500,502 / 503 | 2.1E–08 | 2.3E–12 | 1.1E–01 | 7.1E–08 | 8.0E–12 | 5.2E–03 |
| Pantex | 265,185 / 214 | 4.4E–07 | 3.7E–11 | 2.6E–02 | 1.5E–06 | 1.3E–10 | 2.7E–03 |
| Pinellas | 2,532,174 / 21 | 1.8E–08 | 3.8E–13 | 5.1E–03 | 6.0E–08 | 1.3E–12 | 2.0E–04 |
| PORTS | 639,602 / 1,075 | 1.8E–09 | 2.2E–13 | 2.3E–01 | 6.0E–09 | 7.5E–13 | 1.6E–02 |
| RFETS | 2,171,877 / 344 | 4.0E–07 | 5.4E–12 | 8.1E–02 | 1.4E–06 | 1.8E–11 | 4.0E–03 |
| ANL-E | 7,939,785 / 224 | 2.5E–06 | 1.4E–11 | 8.3E–02 | 8.5E–06 | 4.7E–11 | 1.1E–01 |
| BNL | 5,738,554 / 417 | 2.3E–06 | 3.1E–11 | 8.3E–02 | 7.9E–06 | 1.1E–10 | 1.4E–01 |
| WVDP | 1,698,391 / 464 | 2.1E–06 | 3.1E–11 | 6.6E–02 | 7.0E–06 | 1.0E–10 | 4.5E–02 |
| NTS | 14,266 / 108 | 1.6E–12 | 4.1E–16 | 1.3E–02 | 5.5E–12 | 1.4E–15 | 1.0E–03 |
| Total | | 2.9E–02 | 2.9E–07 | 3.1 | 9.8E–02 | 9.7E–07 | 3.0 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–27. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 2, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Hanford | 377,645 / 843 | 4.2E–06 | 8.5E–11 | 2.9E–01 | 1.4E–05 | 2.9E–10 | 3.6E–01 |
| KAPL-K | 1,290,172 / 650 | 5.3E–04 | 1.2E–08 | 1.5E–01 | 1.8E–03 | 4.0E–08 | 2.0E–02 |
| LBL | 5,856,829 / 174 | 1.8E–02 | 2.9E–07 | 5.1E–02 | 6.2E–02 | 9.7E–07 | 2.7E–02 |
| LANL | 159,152 / 902 | 2.1E–04 | 2.2E–08 | 3.3E–01 | 7.1E–04 | 7.5E–08 | 4.9E–01 |
| NTS | 14,266 / 64 | 1.4E–12 | 3.6E–16 | 6.5E–03 | 4.9E–12 | 1.2E–15 | 1.0E–03 |
| ORNL | 881,652 / 382 | 1.2E–05 | 3.5E–10 | 1.2E–01 | 3.9E–05 | 1.2E–09 | 2.5E–01 |
| SNL-NM | 610,714 / 210 | 1.8E–06 | 7.2E–11 | 5.1E–02 | 6.2E–06 | 2.4E–10 | 1.5E–03 |
| SRS | 620,618 / 2,008 | 1.9E–05 | 1.8E–10 | 6.7E–01 | 6.3E–05 | 5.9E–10 | 8.0E–01 |
| INEL | 153,061 / 1,032 | 1.3E–06 | 1.6E–10 | 4.3E–01 | 4.4E–06 | 5.4E–10 | 7.2E–01 |
| ANL-E | 7,939,785 / 224 | 2.5E–06 | 1.4E–11 | 8.3E–02 | 8.5E–06 | 4.7E–11 | 1.1E–01 |
| KCP | 1,729,833 / 11 | 1.1E–09 | 4.8E–14 | 2.6E–03 | 3.6E–09 | 1.6E–13 | 1.0E–04 |
| LLNL | 6,324,234 / 227 | 1.0E–02 | 1.6E–07 | 5.9E–02 | 3.4E–02 | 5.5E–07 | 8.9E–03 |
| Mound | 3,032,983 / 435 | 1.0E–07 | 5.9E–12 | 1.1E–01 | 3.5E–07 | 2.0E–11 | 4.7E–03 |
| K-25 | 871,406 / 1,259 | 3.2E–07 | 7.0E–12 | 1.2E–01 | 1.1E–06 | 2.4E–11 | 1.9E–02 |
| Y-12 | 895,379 / 618 | 4.0E–08 | 1.5E–12 | 6.7E–02 | 1.4E–07 | 5.0E–12 | 7.1E–03 |
| PGDP | 500,502 / 503 | 2.1E–08 | 2.3E–12 | 1.1E–01 | 7.1E–08 | 8.0E–12 | 5.2E–03 |
| Pantex | 265,185 / 214 | 4.4E–07 | 3.7E–11 | 2.6E–02 | 1.5E–06 | 1.3E–10 | 2.7E–03 |
| Pinellas | 2,532,174 / 21 | 1.8E–08 | 3.8E–13 | 5.1E–03 | 6.0E–08 | 1.3E–12 | 2.0E–04 |
| PORTS | 639,602 / 1,075 | 1.8E–09 | 2.2E–13 | 2.3E–01 | 6.0E–09 | 7.5E–13 | 1.6E–02 |
| RFETS | 2,171,877 / 344 | 4.0E–07 | 5.4E–12 | 8.1E–02 | 1.4E–06 | 1.8E–11 | 4.0E–03 |
| BNL | 5,738,554 / 417 | 2.3E–06 | 3.1E–11 | 8.3E–02 | 7.9E–06 | 1.1E–10 | 1.4E–01 |
| WVDP | 1,698,391 / 464 | 2.1E–06 | 3.1E–11 | 6.6E–02 | 7.0E–06 | 1.0E–10 | 4.5E–02 |
| Total | | 2.9E–02 | 2.9E–07 | 3.1 | 9.8E–02 | 9.7E–07 | 3.0 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–28. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 2, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Fernald | 2,764,589 / 461 | 2.3E-01 | 4.4E-06 | 1.2E-01 | 7.9E-01 | 1.5E-05 | 2.3E-02 |
| Hanford | 377,645 / 1,569 | 3.6E-06 | 7.3E-11 | 5.2E-01 | 1.2E-05 | 2.5E-10 | 6.9E-01 |
| INEL | 153,061 / 1,809 | 1.4E-06 | 1.7E-10 | 5.4E-01 | 4.6E-06 | 5.7E-10 | 5.8E-01 |
| KAPL-K | 1,290,172 / 650 | 5.3E-04 | 1.2E-08 | 1.5E-01 | 1.8E-03 | 4.0E-08 | 2.0E-02 |
| LBL | 5,856,829 / 174 | 1.8E-02 | 2.9E-07 | 5.1E-02 | 6.2E-02 | 9.7E-07 | 2.7E-02 |
| LLNL | 6,324,234 / 483 | 3.9E-01 | 6.3E-06 | 1.5E-01 | 1.3 | 2.1E-05 | 1.7E-01 |
| LANL | 159,152 / 1,362 | 7.8E-03 | 8.2E-07 | 4.9E-01 | 2.7E-02 | 2.8E-06 | 6.5E-01 |
| ORNL | 881,652 / 3,660 | 8.2E-05 | 2.5E-09 | 6.9E-01 | 2.8E-04 | 8.5E-09 | 1.1 |
| PORTS | 639,602 / 3,434 | 5.3E-05 | 6.6E-09 | 7.4E-01 | 1.8E-04 | 2.2E-08 | 9.6E-02 |
| SNL-NM | 610,714 / 210 | 1.8E-06 | 7.2E-11 | 5.1E-02 | 6.2E-06 | 2.4E-10 | 1.5E-03 |
| SRS | 620,618 / 2,598 | 6.1E-04 | 5.7E-09 | 8.3E-01 | 2.1E-03 | 2.0E-08 | 9.6E-01 |
| KCP | 1,729,833 / 11 | 1.1E-09 | 4.8E-14 | 2.6E-03 | 3.6E-09 | 1.6E-13 | 1.0E-04 |
| Mound | 3,032,983 / 435 | 1.0E-07 | 5.9E-12 | 1.1E-01 | 3.5E-07 | 2.0E-11 | 4.7E-03 |
| RFETS | 2,171,877 / 800 | 1.9E-04 | 2.5E-09 | 2.2E-01 | 6.3E-04 | 8.6E-09 | 4.0E-03 |
| K-25 | 871,406 / 1,040 | 6.1E-08 | 1.3E-12 | 8.9E-02 | 2.1E-07 | 4.5E-12 | 1.9E-02 |
| Y-12 | 895,379 / 498 | 1.4E-08 | 5.1E-13 | 5.4E-02 | 4.7E-08 | 1.7E-12 | 7.1E-03 |
| Pinellas | 2,532,174 / 21 | 1.8E-08 | 3.8E-13 | 5.1E-03 | 6.0E-08 | 1.3E-12 | 2.0E-04 |
| Pantex | 265,185 / 216 | 4.4E-07 | 3.7E-11 | 2.6E-02 | 1.5E-06 | 1.3E-10 | 2.7E-03 |
| ANL-E | 7,939,785 / 224 | 2.5E-06 | 1.4E-11 | 8.3E-02 | 8.5E-06 | 4.7E-11 | 1.1E-01 |
| PGDP | 500,502 / 800 | 1.9E-06 | 2.1E-10 | 1.9E-01 | 6.4E-06 | 7.1E-10 | 5.8E-03 |
| BNL | 5,738,554 / 417 | 2.3E-06 | 3.1E-11 | 8.3E-02 | 7.9E-06 | 1.1E-10 | 1.4E-01 |
| WVDP | 1,698,391 / 463 | 2.1E-06 | 3.1E-11 | 6.6E-02 | 7.2E-06 | 1.1E-10 | 4.5E-02 |
| NTS | 14,266 / 108 | 1.6E-12 | 4.1E-16 | 1.3E-02 | 5.5E-12 | 1.4E-5 | 1.0E-03 |
| Total | | 6.4E-01 | 6.3E-06 | 5.2 | 2.2 | 2.1E-05 | 4.6 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–29. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 4, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Hanford | 377,645 / 1,634 | 4.7E–02 | 9.6E–07 | 5.4E–01 | 1.6E–01 | 3.3E–06 | 7.2E–01 |
| INEL | 153,061 / 1,809 | 1.4E–06 | 1.7E–10 | 5.4E–01 | 4.6E–06 | 5.7E–10 | 5.8E–01 |
| KAPL-K | 1,290,172 / 650 | 5.3E–04 | 1.2E–08 | 1.5E–01 | 1.8E–03 | 4.0E–08 | 2.0E–02 |
| LBL | 5,856,829 / 174 | 1.8E–02 | 2.9E–07 | 5.1E–02 | 6.2E–02 | 9.7E–07 | 2.7E–02 |
| LANL | 159,152 / 2,731 | 7.8E–03 | 8.2E–07 | 9.3E–01 | 2.7E–02 | 2.8E–06 | 1.2 |
| ORNL | 881,652 / 3,579 | 8.2E–05 | 2.5E–09 | 6.7E–01 | 2.8E–04 | 8.5E–09 | 1.1 |
| PORTS | 639,602 / 3,483 | 1.9E–02 | 2.3E–06 | 7.6E–01 | 6.4E–02 | 7.9E–06 | 1.3E–01 |
| SNL-NM | 610,714 / 210 | 1.8E–06 | 7.2E–11 | 5.1E–02 | 6.2E–06 | 2.4E–10 | 1.5E–03 |
| SRS | 620,618 / 2,598 | 6.1E–04 | 5.7E–09 | 8.3E–01 | 2.1E–03 | 2.0E–08 | 9.6E–01 |
| KCP | 1,729,833 / 11 | 1.1E–09 | 4.8E–14 | 2.6E–03 | 3.6E–09 | 1.6E–13 | 1.0E–04 |
| LLNL | 6,324,234 / 227 | 4.4E–03 | 7.1E–08 | 5.9E–02 | 1.5E–02 | 2.4E–07 | 8.9E–03 |
| Mound | 3,032,983 / 435 | 1.0E–07 | 5.9E–12 | 1.1E–01 | 3.5E–07 | 2.0E–11 | 4.7E–03 |
| NTS | 14,266 / 108 | 1.6E–12 | 4.1E–16 | 1.3E–02 | 5.5E–12 | 1.4E–15 | 1.0E–03 |
| K-25 | 871,406 / 1,040 | 6.1E–08 | 1.3E–12 | 8.9E–02 | 2.1E–07 | 4.5E–12 | 1.9E–02 |
| Y-12 | 895,379 / 498 | 1.4E–08 | 5.1E–13 | 5.4E–02 | 4.7E–08 | 1.7E–12 | 7.1E–03 |
| PGDP | 500,502 / 497 | 2.1E–08 | 2.4E–12 | 1.1E–01 | 7.2E–08 | 8.0E–12 | 5.2E–03 |
| Pantex | 265,185 / 214 | 4.4E–07 | 3.7E–11 | 2.6E–02 | 1.5E–06 | 1.3E–10 | 2.7E–03 |
| Pinellas | 2,532,174 / 21 | 1.8E–08 | 3.8E–13 | 5.1E–03 | 6.0E–08 | 1.3E–12 | 2.0E–04 |
| RFETS | 2,171,877 / 800 | 1.9E–04 | 2.5E–09 | 2.2E–01 | 6.3E–04 | 8.6E–09 | 4.0E–03 |

***Table D.3.2–29. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 4, by Site—Continued***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| ANL-E | 7,939,785 / 224 | 2.5E–06 | 1.4E–11 | 8.3E–02 | 8.5E–06 | 4.7E–11 | 1.1E–01 |
| BNL | 5,738,554 / 417 | 2.3E–06 | 3.1E–11 | 8.3E–02 | 7.9E–06 | 1.1E–10 | 1.4E–01 |
| WVDP | 1,698,391 / 463 | 2.1E–06 | 3.1E–11 | 6.6E–02 | 7.2E–06 | 1.1E–10 | 4.5E–02 |
| Total | | 9.7E–02 | 2.3E–06 | 5.4 | 3.3E–01 | 7.9E–06 | 5.1 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–30. Programwide Risks Associated With Treatment of LLW Under Centralized Alternatives 3 and 4, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Hanford | 377,645 / 1,634 | 5.0E–02 | 1.0E–06 | 5.4E–01 | 1.7E–01 | 3.5E–06 | 7.2E–01 |
| INEL | 153,061 / 1,809 | 1.4E–06 | 1.7E–10 | 5.4E–01 | 4.6E–06 | 5.7E–10 | 5.8E–01 |
| KAPL-K | 1,290,172 / 650 | 5.3E–04 | 1.2E–08 | 1.5E–01 | 1.8E–03 | 4.0E–08 | 2.0E–02 |
| LBL | 5,856,829 / 174 | 1.8E–02 | 2.9E–07 | 5.1E–02 | 6.2E–02 | 9.7E–07 | 2.7E–02 |
| LANL | 159,152 / 2,731 | 7.8E–03 | 8.2E–07 | 9.3E–01 | 2.7E–02 | 2.8E–06 | 1.2 |
| NTS | 14,266 / 108 | 1.6E–12 | 4.1E–16 | 1.3E–02 | 5.5E–12 | 1.4E–15 | 1.0E–03 |
| ORNL | 881,652 / 3,695 | 8.9E–05 | 2.7E–09 | 7.1E–01 | 3.0E–04 | 9.2E–09 | 1.1 |
| PORTS | 639,602 / 3,481 | 1.9E–02 | 2.3E–06 | 7.6E–01 | 6.4E–02 | 7.9E–06 | 1.3E–01 |
| SNL-NM | 610,714 / 232 | 1.8E–06 | 7.2E–11 | 7.7E–02 | 6.2E–06 | 2.4E–10 | 7.6E–02 |
| SRS | 620,618 / 2,598 | 6.1E–04 | 5.7E–09 | 8.3E–01 | 2.1E–03 | 2.0E–08 | 9.6E–01 |
| ANL-E | 7,939,785 / 224 | 2.5E–06 | 1.4E–11 | 8.3E–02 | 8.5E–06 | 4.7E–11 | 1.1E–01 |
| KCP | 1,729,833 / 11 | 1.1E–09 | 4.8E–14 | 2.6E–03 | 3.6E–09 | 1.6E–13 | 1.0E–04 |
| LLNL | 6,324,234 / 227 | 4.4E–03 | 7.1E–08 | 5.9E–02 | 1.5E–02 | 2.4E–07 | 8.9E–03 |
| Mound | 3,032,983 / 435 | 1.0E–07 | 5.9E–12 | 1.1E–01 | 3.5E–07 | 2.0E–11 | 4.7E–03 |
| K-25 | 871,406 / 1,044 | 8.2E–08 | 1.8E–12 | 9.0E–02 | 2.8E–07 | 6.1E–12 | 1.9E–02 |
| Y-12 | 895,379 / 507 | 1.7E–08 | 6.3E–13 | 5.5E–02 | 5.8E–08 | 2.2E–12 | 7.1E–03 |
| PGDP | 500,502 / 497 | 2.1E–08 | 2.4E–12 | 1.1E–01 | 7.2E–08 | 8.0E–12 | 5.2E–03 |
| Pantex | 265,185 / 214 | 4.4E–07 | 3.7E–11 | 2.6E–02 | 1.5E–06 | 1.3E–10 | 2.7E–03 |
| Pinellas | 2,532,174 / 21 | 1.8E–08 | 3.8E–13 | 5.1E–03 | 6.0E–08 | 1.3E–12 | 2.0E–04 |

***Table D.3.2–30. Programwide Risks Associated With Treatment of LLW Under Centralized Alternatives 3 and 4, by Site—Continued***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| RFETS | 2,171,877 / 800 | 1.9E–04 | 2.5E–09 | 2.2E–01 | 6.3E–04 | 8.6E–09 | 4.0E–03 |
| BNL | 5,738,554 / 417 | 2.3E–06 | 3.1E–11 | 8.3E–02 | 7.9E–06 | 1.E–10 | 1.4E–01 |
| WVDP | 1,698,391 / 463 | 2.1E–06 | 3.1E–11 | 6.6E–02 | 7.2E–06 | 1.E–10 | 4.5E–02 |
| Total | | 1.0E–01 | 2.3E–06 | 5.4 | 3.4E–01 | 7.9E–06 | 5.1 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–31. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 5, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Hanford | 377,645 / 1,634 | 4.7E–02 | 9.6E–07 | 5.4E–01 | 1.6E–01 | 3.3E–06 | 7.2E–01 |
| INEL | 153,061 / 3,954 | 4.1E–04 | 5.1E–08 | 1.3 | 1.4E–03 | 1.7E–07 | 1.9 |
| KAPL-K | 1,290,172 / 650 | 5.3E–04 | 1.2E–08 | 1.5E–01 | 1.8E–03 | 4.0E–08 | 2.0E–02 |
| LBL | 5,856,829 / 174 | 1.8E–02 | 2.9E–07 | 5.1E–02 | 6.2E–02 | 9.7E–07 | 2.7E–02 |
| LANL | 159,152 / 902 | 2.1E–04 | 2.2E–08 | 3.3E–01 | 7.1E–04 | 7.5E–08 | 4.9E–01 |
| ORNL | 881,652 / 4,281 | 3.0E–01 | 9.3E–06 | 8.5E–01 | 1.0 | 3.2E–05 | 1.5 |
| SNL-NM | 610,714 / 210 | 1.8E–06 | 7.2E–11 | 5.1E–02 | 6.2E–06 | 2.4E–10 | 1.5E–03 |
| SRS | 620,618 / 2,598 | 6.1E–04 | 5.7E–09 | 8.3E–01 | 2.1E–03 | 2.0E–08 | 9.6E–01 |
| ANL-E | 7,939,785 / 224 | 2.5E–06 | 1.4E–11 | 8.3E–02 | 8.5E–06 | 4.7E–11 | 1.1E–01 |
| KCP | 1,729,833 / 11 | 1.1E–09 | 4.8E–14 | 2.6E–03 | 3.6E–09 | 1.6E–13 | 1.0E–04 |
| LLNL | 6,324,234 / 227 | 4.4E–03 | 7.1E–08 | 5.9E–02 | 1.5E–02 | 2.4E–07 | 8.9E–03 |
| Mound | 3,032,983 / 435 | 1.0E–07 | 5.9E–12 | 1.1E–01 | 3.5E–07 | 2.0E–11 | 4.7E–03 |
| NTS | 14,266 / 108 | 1.6E–12 | 4.1E–16 | 1.3E–02 | 5.5E–12 | 1.4E–15 | 1.0E–03 |
| K-25 | 871,406 / 1,040 | 6.1E–08 | 1.3E–12 | 8.9E–02 | 2.1E–07 | 4.5E–12 | 1.9E–02 |
| Y-12 | 895,379 / 498 | 1.4E–08 | 5.1E–13 | 5.4E–02 | 4.7E–08 | 1.7E–12 | 7.1E–03 |
| PGDP | 500,502 / 497 | 2.1E–08 | 2.4E–12 | 1.1E–01 | 7.2E–08 | 8.0E–12 | 5.2E–03 |
| Pantex | 265,185 / 214 | 4.4E–07 | 3.7E–11 | 2.6E–02 | 1.5E–06 | 1.3E–10 | 2.7E–03 |
| Pinellas | 2,532,174 / 21 | 1.8E–08 | 3.8E–13 | 5.1E–03 | 6.0E–08 | 1.3E–12 | 2.0E–04 |
| PORTS | 639,602 / 1,087 | 1.8E–09 | 2.2E–13 | 2.4E–01 | 5.9E–09 | 7.5E–13 | 1.6E–02 |

***Table D.3.2–31. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 5, by Site—Continued***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| RFETS | 2,171,877<br>344 | 4.0E–07 | 5.4E–12 | 8.1E–02 | 1.4E–06 | 1.8E–11 | 4.0E–03 |
| BNL | 5,738,554<br>417 | 2.3E–06 | 3.1E–11 | 8.3E–02 | 7.9E–06 | 1.1E–10 | 1.4E–01 |
| WVDP | 1,698,391<br>463 | 2.1E–06 | 3.1E–11 | 6.6E–02 | 7.2E–06 | 1.1E–10 | 4.5E–10 |
| Total | | 3.7E–01 | 9.3E–06 | 5.1 | 1.2 | 3.2E–05 | 5.9 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–32. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 5, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Hanford | 377,645 / 9,856 | 7.5E–02 | 1.5E–06 | 3.7 | 2.5E–01 | 5.2E–06 | 5.3 |
| KAPL-K | 1,290,172 / 650 | 5.3E–04 | 1.2E–08 | 1.5E–01 | 1.8E–03 | 4.0E–08 | 2.0E–02 |
| LBL | 5,856,829 / 174 | 1.8E–02 | 2.9E–07 | 5.1E–02 | 6.2E–02 | 9.7E–07 | 2.7E–02 |
| LANL | 159,152 / 902 | 2.1E–04 | 2.2E–08 | 3.3E–01 | 7.1E–04 | 7.5E–08 | 4.9E–01 |
| SNL-NM | 610,714 / 210 | 1.8E–06 | 7.2E–11 | 5.1E–02 | 6.2E–06 | 2.4E–10 | 1.5E–03 |
| SRS | 620,618 / 1,986 | 1.2E–05 | 1.2E–10 | 6.6E–01 | 4.2E–05 | 3.9E–10 | 7.9E–01 |
| INEL | 153,061 / 677 | 8.0E–07 | 9.9E–11 | 3.2E–01 | 2.7E–06 | 3.4E–10 | 5.8E–01 |
| ORNL | 881,652 / 382 | 1.2E–05 | 3.5E–10 | 1.2E–01 | 3.9E–05 | 1.2E–09 | 2.5E–01 |
| KCP | 1,729,833 / 11 | 1.1E–09 | 4.8E–14 | 2.6E–03 | 3.6E–09 | 1.6E–13 | 1.0E–04 |
| ANL-E | 7,939,785 / 224 | 2.5E–06 | 1.4E–11 | 8.3E–02 | 8.5E–06 | 4.7E–11 | 1.1E–01 |
| LLNL | 6,324,234 / 227 | 4.4E–03 | 7.1E–08 | 5.9E–02 | 1.5E–02 | 2.4E–07 | 8.9E–03 |
| Mound | 3,032,983 / 435 | 1.0E–07 | 5.9E–12 | 1.1E–01 | 3.5E–07 | 2.0E–11 | 4.7E–03 |
| K-25 | 871,406 / 1,259 | 3.2E–07 | 7.0E–12 | 1.2E–01 | 1.1E–06 | 2.4E–11 | 1.9E–02 |
| Y-12 | 895,379 / 618 | 4.0E–08 | 1.5E–12 | 6.7E–02 | 1.4E–07 | 5.0E–12 | 7.1E–03 |
| PGDP | 500,502 / 497 | 2.1E–08 | 2.4E–12 | 1.1E–01 | 7.2E–08 | 8.0E–12 | 5.2E–03 |
| Pantex | 265,185 / 214 | 4.4E–07 | 3.7E–11 | 2.6E–02 | 1.5E–06 | 1.3E–10 | 2.7E–03 |
| Pinellas | 2,532,174 / 21 | 1.8E–08 | 3.8E–13 | 5.1E–03 | 6.0E–08 | 1.3E–12 | 2.0E–04 |
| PORTS | 639,602 / 1,087 | 1.8E–09 | 2.2E–13 | 2.4E–01 | 5.9E–09 | 7.5E–13 | 1.6E–02 |

***Table D.3.2–32. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 5, by Site—Continued***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| RFETS | 2,171,877 / 344 | 4.0E-07 | 5.4E-12 | 8.1E-02 | 1.4E-06 | 1.8E-11 | 4.0E-03 |
| BNL | 5,738,554 / 417 | 2.3E-06 | 3.1E-11 | 8.3E-02 | 7.9E-06 | 1.1E-10 | 1.4E-01 |
| WVDP | 1,698,391 / 463 | 2.1E-06 | 3.1E-11 | 6.6E-02 | 7.2E-06 | 1.1E-10 | 4.5E-02 |
| NTS | 14,266 / 108 | 1.6E-12 | 4.1E-16 | 1.3E-02 | 5.5E-12 | 1.4E-15 | 1.0E-03 |
| Total | | 9.8E-02 | 1.5E-06 | 6.4 | 3.3E-01 | 5.2E-06 | 7.8 |

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–33. Programwide Risks Associated With Disposal of LLW Under the No Action Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | | |
| | Cancer fatalities | 1.2E+01 | |
| | Cancer incidence | 5.7E–03 | |
| | Genetic effects | 2.0E–02 | |
| | Hazard index | 1.2E–03 | |
| All lifetimes | Dose (person-rem) | | |
| | Cancer fatalities | 1.5E+02 | |
| | Cancer incidence | 7.6E–02 | |
| | Genetic effects | 2.6E–01 | |
| | Hazard index | 1.5E–02 | |
| WM workers | Dose (FTE-rem) | 8.0E+03 | |
| | Cancer fatalities | 3.2 | |
| | Cancer incidence | 1.1E+01 | |
| | Genetic effects | 4.9E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.6 |
| | Construction injuries | | 7.0E+02 |
| | Operation fatalities | | 1.8 |
| | Operation injuries | | 1.4E+02 |

***Table D.3.2–34. Programwide Risks Associated With Disposal of LLW Under the Decentralized Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 1.3E+02 | |
| | Cancer fatalities | 6.7E–02 | |
| | Cancer incidence | 2.3E–01 | |
| | Genetic effects | 1.3E–02 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 2.6E+03 | |
| | Cancer fatalities | 1.3 | |
| | Cancer incidence | 4.5 | |
| | Genetic effects | 2.6E–01 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 6.5E+03 | |
| | Cancer fatalities | 2.6 | |
| | Cancer incidence | 9.0 | |
| | Genetic effects | 3.9E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 3.9 |
| | Construction injuries | | 1.6E+03 |
| | Operation fatalities | | 1.6 |
| | Operation injuries | | 1.3E+03 |

***Table D.3.2–35. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 1, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 3.0 | |
| | Cancer fatalities | 1.5E–03 | |
| | Cancer incidence | 5.1E–03 | |
| | Genetic effects | 3.0E–04 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 4.4E+01 | |
| | Cancer fatalities | 2.2E–02 | |
| | Cancer incidence | 7.4E–02 | |
| | Genetic effects | 4.4E–03 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 6.1E+03 | |
| | Cancer fatalities | 2.5 | |
| | Cancer incidence | 8.6 | |
| | Genetic effects | 3.6 | |
| | Exposure index | | 3.8 |
| | Construction fatalities | | 1.6E+03 |
| | Construction injuries | | 1.6 |
| | Operation fatalities | | 1.3E+03 |
| | Operation injuries | | |

***Table D.3.2–36. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 3, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 2.3 | |
| | Cancer fatalities | 1.1E–03 | |
| | Cancer incidence | 3.9E–03 | |
| | Genetic effects | 2.3E–04 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 3.1E+01 | |
| | Cancer fatalities | 1.6E–02 | |
| | Cancer incidence | 5.3E–02 | |
| | Genetic effects | 3.1E–03 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 6.9E+03 | |
| | Cancer fatalities | 2.8 | |
| | Cancer incidence | 9.6 | |
| | Genetic effects | 4.1E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 3.5 |
| | Construction injuries | | 1.5E+03 |
| | Operation fatalities | | 1.4 |
| | Operation injuries | | 1.0E+03 |

***Table D.3.2–37. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 6, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 3.3E+01 | |
| | Cancer fatalities | 1.6E-02 | |
| | Cancer incidence | 5.6E-02 | |
| | Genetic effects | 3.3E-03 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 4.3E+02 | |
| | Cancer fatalities | 2.2E-01 | |
| | Cancer incidence | 7.3E-01 | |
| | Genetic effects | 4.3E-02 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 4.4E+03 | |
| | Cancer fatalities | 1.8 | |
| | Cancer incidence | 6.2 | |
| | Genetic effects | 2.6E-01 | |
| | Exposure index | | |
| | Construction fatalities | | 5.1 |
| | Construction injuries | | 2.2E+03 |
| | Operation fatalities | | 1.3 |
| | Operation injuries | | 1.1E+03 |

***Table D.3.2–38. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 7, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 3.4E-01 | |
| | Cancer fatalities | 1.7E-04 | |
| | Cancer incidence | 5.9E-04 | |
| | Genetic effects | 3.4E-05 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 3.7 | |
| | Cancer fatalities | 1.8E-03 | |
| | Cancer incidence | 6.3E-03 | |
| | Genetic effects | 3.7E-04 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 3.5E+03 | |
| | Cancer fatalities | 1.4 | |
| | Cancer incidence | 4.9 | |
| | Genetic effects | 2.1E-01 | |
| | Exposure index | | |
| | Construction fatalities | | 4.9 |
| | Construction injuries | | 2.2E+03 |
| | Operation fatalities | | 1.1 |
| | Operation injuries | | 7.8E+02 |

***Table D.3.2–39. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 1, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 9.6 | |
| | Cancer fatalities | 4.8E–03 | |
| | Cancer incidence | 1.6E–02 | |
| | Genetic effects | 9.6E–04 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 1.3E+02 | |
| | Cancer fatalities | 6.4E–02 | |
| | Cancer incidence | 2.2E–01 | |
| | Genetic effects | 1.3E–02 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 6.9E+03 | |
| | Cancer fatalities | 2.8 | |
| | Cancer incidence | 9.7 | |
| | Genetic effects | 4.2E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 4.0E–01 |
| | Construction injuries | | 1.7E+02 |
| | Operation fatalities | | 9.6E–01 |
| | Operation injuries | | 8.1E+02 |

***Table D.3.2–40. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 2, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 0.0 | |
| | Cancer fatalities | 0.0 | |
| | Cancer incidence | 0.0 | |
| | Genetic effects | 0.0 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 0.0 | |
| | Cancer fatalities | 0.0 | |
| | Cancer incidence | 0.0 | |
| | Genetic effects | 0.0 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 5.5E+03 | |
| | Cancer fatalities | 2.2 | |
| | Cancer incidence | 7.7 | |
| | Genetic effects | 3.3E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.7E–01 |
| | Construction injuries | | 4.7E–01 |
| | Operation fatalities | | 4.4E–01 |
| | Operation injuries | | 1.1E+02 |

***Table D.3.2–41. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 2, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 1.0E+01 | |
| | Cancer fatalities | 5.2E–03 | |
| | Cancer incidence | 1.8E–02 | |
| | Genetic effects | 1.0E–03 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 1.5E+02 | |
| | Cancer fatalities | 7.2E–02 | |
| | Cancer incidence | 2.5E–01 | |
| | Genetic effects | 1.5E–02 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 4.9E+03 | |
| | Cancer fatalities | 2.0 | |
| | Cancer incidence | 6.9 | |
| | Genetic effects | 3.0E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 3.0 |
| | Construction injuries | | 1.3E+03 |
| | Operation fatalities | | 1.1 |
| | Operation injuries | | 9.1E+02 |

***Table D.3.2–42. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 4, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 2.7E+01 | |
| | Cancer fatalities | 1.4E–02 | |
| | Cancer incidence | 4.7E–02 | |
| | Genetic effects | 2.7E–03 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 3.6E+02 | |
| | Cancer fatalities | 1.9E–01 | |
| | Cancer incidence | 6.2E–01 | |
| | Genetic effects | 3.6E–02 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 5.3E+03 | |
| | Cancer fatalities | 2.1 | |
| | Cancer incidence | 7.4 | |
| | Genetic effects | 3.2E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 2.8 |
| | Construction injuries | | 1.2E+03 |
| | Operation fatalities | | 9.8E–01 |
| | Operation injuries | | 7.4E+02 |

***Table D.3.2–43. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 3, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 1.8E+01 | |
| | Cancer fatalities | 9.2E–03 | |
| | Cancer incidence | 3.1E–02 | |
| | Genetic effects | 1.8E–03 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 2.5E+02 | |
| | Cancer fatalities | 1.2E–01 | |
| | Cancer incidence | 4.2E–01 | |
| | Genetic effects | 2.5E–02 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 4.4E+03 | |
| | Cancer fatalities | 1.8 | |
| | Cancer incidence | 6.2 | |
| | Genetic effects | 2.7E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 2.5E–01 |
| | Construction injuries | | 1.1E+02 |
| | Operation fatalities | | 6.3E–01 |
| | Operation injuries | | 5.4E+02 |

***Table D.3.2–44. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 4, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 0.0 | |
| | Cancer fatalities | 0.0 | |
| | Cancer incidence | 0.0 | |
| | Genetic effects | 0.0 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 0.0 | |
| | Cancer fatalities | 0.0 | |
| | Cancer incidence | 0.0 | |
| | Genetic effects | 0.0 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 3.9E+03 | |
| | Cancer fatalities | 1.6 | |
| | Cancer incidence | 5.5 | |
| | Genetic effects | 2.3E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 1.0E–01 |
| | Construction injuries | | 2.9E+01 |
| | Operation fatalities | | 2.9E–01 |
| | Operation injuries | | 7.4E+01 |

***Table D.3.2–45. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 5, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 2.7E+01 | |
| | Cancer fatalities | 1.4E–02 | |
| | Cancer incidence | 4.7E–02 | |
| | Genetic effects | 2.7E–03 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 3.6E+02 | |
| | Cancer fatalities | 1.8E–01 | |
| | Cancer incidence | 6.3E–01 | |
| | Genetic effects | 3.6E–02 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 5.3E+03 | |
| | Cancer fatalities | 2.1 | |
| | Cancer incidence | 7.4 | |
| | Genetic effects | 3.2E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 2.8 |
| | Construction injuries | | 1.2E+03 |
| | Operation fatalities | | 9.8E–01 |
| | Operation injuries | | 7.5E+02 |

***Table D.3.2–46. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 5, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Physical Hazards |
|---|---|---|---|
| Maximally exposed farm family | Dose (person-rem) | 1.8E+01 | |
| | Cancer fatalities | 9.2E–03 | |
| | Cancer incidence | 3.1E–02 | |
| | Genetic effects | 1.8E–03 | |
| | Hazard index | | |
| All lifetimes | Dose (person-rem) | 2.5E+02 | |
| | Cancer fatalities | 1.2E–01 | |
| | Cancer incidence | 4.2E–01 | |
| | Genetic effects | 2.5E–02 | |
| | Hazard index | | |
| WM workers | Dose (FTE-rem) | 4.4E+03 | |
| | Cancer fatalities | 1.8 | |
| | Cancer incidence | 6.2 | |
| | Genetic effects | 2.6E–01 | |
| | Exposure index | | |
| | Construction fatalities | | 2.5E–01 |
| | Construction injuries | | 1.1E+02 |
| | Operation fatalities | | 6.3E–01 |
| | Operation injuries | | 5.3E+02 |

***Table D.3.2-47. Programwide Risks Associated With Disposal of LLW Under the No Action Alternative, by Site***

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| LANL (0) | 0.00 | 0.00 | 1.2 | 0.00 | 0.00 | 2.9 |
| NTS (0) | 0.00 | 0.00 | 2.1E-01 | 0.00 | 0.00 | 5.7E-02 |
| SRS (153) | 1.5E-04 | 2.2E-03 | 2.8 | 5.0E-04 | 7.3E-03 | 2.5 |
| ORR (22) | 8.9E-07 | 1.3E-05 | 4.9E-01 | 3.0E-06 | 4.4E-06 | 1.2 |
| Hanford (18) | 5.6E-03 | 8.0E-02 | 1.1 | 1.9E-02 | 2.7E-01 | 2.3 |
| INEL (0) | 0.00 | 0.00 | 8.5E-01 | 0.00 | 0.00 | 2.2 |
| Total | 5.7E-03 | 7.6E-02 | 6.6 | 2.0E-02 | 2.6E-01 | 1.1E+01 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2-48. Programwide Risks Associated With Disposal of LLW Under the Decentralized Alternative, by Site***

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| INEL (0) | 0.00 | 0.00 | 6.6E-01 | 0.00 | 0.00 | 1.5 |
| LLNL (142) | 4.4E-06 | 6.8E-05 | 2.3E-01 | 1.5E-05 | 2.3E-04 | 5.6E-01 |
| LANL (0) | 0.00 | 0.00 | 8.8E-01 | 0.00 | 0.00 | 2.0 |
| ORR (22) | 7.3E-07 | 1.1E-05 | 5.4E-01 | 2.5E-06 | 3.6E-05 | 1.1 |
| SNL-NM (15) | 6.3E-02 | 1.1 | 9.5E-02 | 2.1E-01 | 3.9 | 2.2E-01 |
| PGDP (42) | 3.7E-04 | 6.1E-03 | 1.5E-01 | 1.3E-03 | 2.1E-02 | 1.1E-02 |
| Pantex (0) | 0.00 | 0.00 | 2.1E-02 | 0.00 | 0.00 | 2.0E-03 |
| RFETS (38) | 1.1E-07 | 2.1E-06 | 1.4E-01 | 3.7E-07 | 7.0E-06 | 9.9E-03 |
| SRS (153) | 1.1E-04 | 1.7E-03 | 4.1 | 3.8E-04 | 5.6E-03 | 2.0 |
| PORTS (37) | 2.4E-07 | 4.5E-06 | 4.4E-01 | 8.2E-07 | 1.5E-05 | 4.6E-02 |
| ANL-E (64) | 1.1E-04 | 5.1E-03 | 1.1E-01 | 3.9E-04 | 1.7E-02 | 1.5E-01 |
| Hanford (18) | 1.0E-03 | 1.4E-02 | 5.6E-01 | 3.4E-03 | 4.7E-02 | 1.3 |
| NTS (0) | 0.00 | 0.00 | 1.4E-02 | 0.00 | 0.00 | 1.5E-03 |
| WVDP (90) | 5.3E-04 | 3.8E-02 | 9.3E-02 | 1.8E-03 | 1.3E-01 | 8.7E-02 |
| BNL (78) | 1.8E-03 | 1.1E-01 | 6.0E-02 | 6.3E-03 | 3.8E-01 | 1.3E-01 |
| Total | 6.5E-02 | 1.2 | 8.0 | 2.2E-01 | 4.1 | 9.0 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–49. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 1, by Site***

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| Hanford (18) | 1.0E–03 | 1.4E–02 | 5.6E–01 | 3.4E–03 | 4.7E–02 | 1.3 |
| INEL (0) | 0.00 | 0.00 | 6.6E–01 | 0.00 | 0.00 | 1.5 |
| LLNL (142) | 4.4E–06 | 6.8E–05 | 2.3E–01 | 1.5E–05 | 2.3E–04 | 5.6E–01 |
| LANL (0) | 0.00 | 0.00 | 8.9E–01 | 0.00 | 0.00 | 2.0 |
| ORR (22) | 7.3E–07 | 1.1E–05 | 5.4E–01 | 2.5E–06 | 3.6E–05 | 1.1 |
| PORTS (145) | 2.0E–06 | 7.7E–05 | 5.2E–01 | 6.9E–06 | 2.6E–04 | 1.1E–01 |
| PGDP (42) | 3.7E–04 | 6.1E–03 | 1.5E–01 | 1.3E–03 | 2.1E–02 | 1.1E–02 |
| Pantex (0) | 5.8E–10 | 4.9E–09 | 3.9E–03 | 2.0E–09 | 1.7E–08 | 6.6E–04 |
| SRS (153) | 1.2E–04 | 1.8E–03 | 4.1 | 4.1E–04 | 6.0E–03 | 2.0 |
| RFETS (38) | 1.1E–07 | 2.1E–06 | 1.4E–01 | 3.7E–07 | 7.0E–06 | 9.9E–03 |
| NTS (0) | 0.0 | 0.0 | 1.4E–02 | 0.0 | 0.0 | 1.5E–03 |
| Total | 1.5E–03 | 2.2E–02 | 7.8 | 5.1E–03 | 7.4E–02 | 8.6 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–50. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 3, by Site***

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| Hanford (18) | 1.0E–03 | 1.4E–02 | 5.6E–01 | 3.4E–03 | 4.7E–02 | 1.3 |
| INEL (0) | 0.00 | 0.00 | 6.6E–01 | 0.00 | 0.00 | 1.5 |
| LANL (0) | 0.00 | 0.00 | 1.2 | 0.00 | 0.00 | 2.7 |
| NTS (0) | 0.00 | 0.00 | 8.0E–02 | 0.00 | 0.00 | 1.3E–01 |
| ORR (22) | 5.0E–07 | 7.2E–06 | 9.5E–01 | 1.7E–06 | 2.5E–05 | 1.9E+00 |
| SRS (153) | 1.2E–04 | 1.8E–03 | 4.1 | 4.1E–04 | 6.0E–03 | 2.0 |
| Total | 1.1E–03 | 1.6E–02 | 7.6 | 3.9E–03 | 5.3E–02 | 9.6 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–51. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 6, by Site***

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| Hanford (18) | 1.6E–02 | 2.2E–01 | 1.8 | 5.5E–02 | 7.3E–01 | 4.0 |
| SRS (23) | 1.7E–04 | 1.9E–03 | 6.4 | 5.9E–04 | 6.6E–03 | 2.1 |
| Total | 1.6E–02 | 2.2E–01 | 8.2 | 5.6E–02 | 7.4E–01 | 6.2 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–52. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 7, by Site***

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| NTS (0) | 0.00 | 0.00 | 1.1 | 0.00 | 0.00 | 2.8 |
| SRS (23) | 1.7E–04 | 1.9E–03 | 6.4 | 5.9E–04 | 6.3E–03 | 2.1 |
| Total | 1.7E–04 | 1.9E–03 | 7.5 | 5.9E–04 | 6.3E–03 | 4.9 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–53. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 1, by Site***

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| Hanford (18) | 4.8E–03 | 6.4E–02 | 4.1 | 1.6E–02 | 2.2E–01 | 9.7 |
| Total | 4.8E–03 | 6.4E–02 | 4.1 | 1.6E–02 | 2.2E–01 | 9.7 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

*Table D.3.2–54. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 2, by Site*

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| NTS (0) | 0.00 | 0.00 | 2.8 | 0.00 | 0.00 | 7.7 |
| Total | 0.00 | 0.00 | 2.8 | 0.00 | 0.00 | 7.7 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

*Table D.3.2–55. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 2, by Site*

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| Hanford (18) | 4.5E–03 | 6.2E–02 | 4.3E–01 | 1.5E–02 | 2.1E–01 | 1.1 |
| INEL (0) | 0.00 | 0.00 | 4.9E–01 | 0.00 | 0.00 | 1.2 |
| LLNL (142) | 4.4E–06 | 6.8E–05 | 1.9E–01 | 1.5E–05 | 2.3E–04 | 4.7E–01 |
| LANL (0) | 0.00 | 0.00 | 5.3E–01 | 0.00 | 0.00 | 1.3 |
| ORR (22) | 1.6E–06 | 2.3E–05 | 3.5E–01 | 5.3E–06 | 7.7E–05 | 7.4E–01 |
| PORTS (145) | 3.5E–06 | 1.3E–04 | 3.2E–01 | 1.2E–05 | 4.5E–04 | 9.3E–02 |
| PGDP (42) | 5.0E–04 | 8.1E–03 | 1.3E–01 | 1.7E–03 | 2.8E–02 | 9.7E–03 |
| Pantex (0) | 0.00 | 0.00 | 2.1E–02 | 0.00 | 0.00 | 2.0E–03 |
| SRS (153) | 1.4E–04 | 2.1E–03 | 3.5 | 4.9E–04 | 7.2E–03 | 2.0 |
| RFETS (38) | 3.2E–07 | 6.2E–06 | 6.8E–02 | 1.1E–06 | 2.1E–05 | 5.6E–03 |
| NTS (0) | 0.0 | 0.0 | 3.8E–03 | 0.0 | 0.0 | 4.0E–04 |
| Total | 5.2E–03 | 7.2E–02 | 6.1 | 1.8E–02 | 2.5E–01 | 6.9 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–56. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 4, by Site***

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| LANL (0 | 0.00 | 0.00 | 5.7E–01 | 0.00 | 0.00 | 1.4 |
| ORR (22) | 7.4E–07 | 1.1E–05 | 7.7E–01 | 2.5E–06 | 3.6E–05 | 1.7 |
| NTS (0) | 0.00 | 0.00 | 2.2E–02 | 0.00 | 0.00 | 2.7E–02 |
| SRS (153) | 1.4E–04 | 2.1E–03 | 3.5 | 4.9E–04 | 7.2E–03 | 2.0 |
| INEL (0) | 0.00 | 0.00 | 5.2E–01 | 0.00 | 0.00 | 1.3 |
| Hanford (18) | 1.4E–02 | 1.8E–01 | 4.3E–01 | 4.6E–02 | 6.1E–01 | 1.1 |
| Total | 1.4E–02 | 1.9E–01 | 5.9 | 4.7E–02 | 6.2E–01 | 7.5 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–57. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 3, by Site***

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| Hanford (18) | 9.2E–03 | 1.2E–01 | 2.7 | 3.1E–02 | 4.2E–01 | 6.2 |
| Total | 9.2E–03 | 1.2E–01 | 2.7 | 3.1E–02 | 4.2E–01 | 6.2 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

*Table D.3.2–58. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 4, by Site*

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| NTS (0) | 0.00 | 0.00 | 2.0 | 0.00 | 0.00 | 5.5 |
| Total | 0.00 | 0.00 | 2.0 | 0.00 | 0.00 | 5.5 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

*Table D.3.2–59. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 5, by Site*

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| Hanford (18) | 1.4E–02 | 1.8E–01 | 4.3E–01 | 4.6E–02 | 6.1E–01 | 1.1 |
| LANL (0) | 0.00 | 0.00 | 5.9E–01 | 0.00 | 0.00 | 1.4 |
| ORR (22) | 7.4E–07 | 1.1E–05 | 7.7E–01 | 2.5E–06 | 3.6E–05 | 1.7 |
| NTS (0) | 0.00 | 0.00 | 2.2E–02 | 0.00 | 0.00 | 2.7E–02 |
| SRS (153) | 1.4E–04 | 2.1E–03 | 3.5 | 4.9E–04 | 7.2E–03 | 2.0 |
| INEL (0) | 0.00 | 0.00 | 4.9E–01 | 0.00 | 0.00 | 1.2 |
| Total | 1.4E–02 | 1.8E–01 | 5.9 | 4.7E–02 | 6.2E–01 | 7.5 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

***Table D.3.2–60. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 5, by Site***

| Site (Lifetime) | Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers | Maximally Exposed Farm Family | All Farm Family Lifetimes | WM Workers |
| Hanford (18) | 9.2E–03 | 1.2E–01 | 2.6 | 3.1E–02 | 4.2E–01 | 6.2 |
| Total | 9.2E–03 | 1.2E–01 | 2.6 | 3.1E–02 | 4.2E–01 | 6.2 |

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

### D.3.2.4 Results of the LLW Human Health Risk Analysis for Routine Operations

#### D.3.2.4.1 *Programwide Trends in Human Health Risks Associated With LLW Management Alternatives*

In general, No Action presents the lowest health risks for all public populations and for all health risk endpoints. For the offsite population the risks of cancer fatality due to the treatment of LLW are within 2.5 orders of magnitude for all alternatives (2.0E–03 to 6.4E–01). Risks to the noninvolved worker population and to MEIs follow the same general trend. Regionalized Alternative 2 (regionalized volume reduction at 11 installations) produces the highest risk of cancer fatalities, though it is still within an order of magnitude of all the other alternatives. The health risks tend to increase as the level of treatment increases and where a treatment installation is situated in a highly populated area.

Overall, estimated worker health risks associated with management of LLW are similar among alternatives; however, the highest worker risks tend to be for installations with waste consolidation (i.e., larger waste loads) for treatment and for installations with more treatment facility construction.

Estimated impacts to each of the receptor populations are presented below.

**Offsite Population.** The lowest risks of cancer fatality to the offsite population are from the No Action Alternative (2.0E–03), the Decentralized Alternative, Regionalized Alternatives 1, 3, 6, 7, and Centralized Alternatives 1 and 2. All are in the E–02 order of magnitude and affect a total population of 44 million people. Except for the No Action Alternative, all of these installations perform minimum treatment (although some volume reduction is performed in the No Action Alternative); the only variation is in the various disposal configurations. The risks of cancer fatality associated with Regionalized Alternatives 4 and 5 and Centralized Alternatives 3, 4, and 5 are similar to one another (ranging from 9.7E–02 to 3.7E–01 over a total affected population of approximately 44 million) and are about 0.5 to 2 orders of magnitude higher than for the other alternatives.

Regionalized 2 poses the highest risks to the offsite population by approximately 0.5 orders of magnitude (an estimated 6.4E–01 cancer fatalities over 47 million people). This is because the largest combined population (11 sites totaling about 14.8 million people) is affected by volume reduction (which includes

incineration). The highest installation-specific risks are associated with LLNL (an estimated 3.9E–01 cancer fatalities over a population of approximately 6.3 million); the radionuclide contributing the most risk is tritium, via inhalation and ingestion. The lowest risks to an offsite population at a particular installation are at NTS for all alternatives.

Inspection of Table D.3.2–6 shows that for all alternatives in which incineration is the major volume-reduction treatment (Regionalized 2, 4, and 5, and Centralized 3, 4, and 5), cancer fatality risks in the E–01 order of magnitude are attributable to tritium except in Regionalized 4, and Centralized 3 and 4. In these three alternatives, both tritium and uranium–238 contribute cancer fatality risks on the order of E–01.

**Noninvolved Worker Population.** The trends in programwide health risks to the noninvolved worker population are similar to those observed for the offsite population; both the programwide risks and the total affected population are lower by approximately 2 orders of magnitude.

The estimated risk of cancer fatality to the noninvolved worker population in Regionalized 2 (6.6E–03 cancer fatalities in a population of 126,415) are about three to six times higher than in the other volume reduction alternatives. The smallest risk of cancer fatality (6.0E–05) occurs in the No Action Alternative.

The risks in the Decentralized, Regionalized 1, 3, 6, 7, and Centralized 1 and 2 Alternatives are identical to one another (1.9E–04) because the treatment is the same at all sites. The risks to the noninvolved worker population are 1 to 1.5 orders of magnitude higher in Regionalized 4, and 5 and Centralized 3, 4, and 5 than in the minimum treatment alternatives.

**Maximally Exposed Noninvolved Workers and Maximally Exposed Offsite Individuals.** Radiological exposure risks to the noninvolved worker and offsite MEIs are lowest in the No Action Alternative; the Decentralized, Regionalized 1, 3, 6, 7, and Centralized 1 and 2 Alternatives are higher by 2 to 3 orders of magnitude. Another order of magnitude higher occurs in Regionalized 4 and Centralized 3, 4, and 5. The highest radiological exposure risks to the noninvolved worker and offsite MEIs occur in Regionalized 2 and 5.

The programwide risk of cancer incidence for both MEIs is in the E–05 to E–07 range in Regionalized 2, 4, and 5 and Centralized 3, 4, and 5 (see Table D.3.2–5). Across the program, the highest risk of cancer fatality for both MEIs is in Regionalized 5 (an estimated risk of 9.3E–06 for the offsite MEI and 4.1E–06

for the noninvolved worker MEI). At the installation level, the highest risks of cancer fatality to the offsite MEI are at FEMP (4.4E–06) and LLNL (6.3E–06) in Regionalized 2; PORTS (2.3E–06) in Regionalized 4; Hanford (1.0E–06) and PORTS (2.3E–06) in Centralized 3 and 4; ORNL (9.3E–06) in Regionalized 5; and Hanford (1.5E–06) in Centralized 5. These elevated risks are the result of volume reduction (including incineration) of relatively large volumes of volatile waste containing tritium. All cancer fatality risks to both MEIs for minimum treatment alternatives are below E–06.

**Workers.** The programwide estimated risks of cancer fatality to workers vary by no more than a factor of three across all alternatives. The risks for the minimum treatment alternatives (Decentralized, Regionalized 1, 3, 6, and 7 and Centralized 1 and 2) are nearly identical to one another (approximately 8.3E–01 cancer fatalities across 10,191 to 12,077 FTEs), and are slightly higher in the No Action Alternative and volume reduction alternatives Regionalized 2, 4, and 5, and Centralized 3 and 4). The highest programwide cancer fatality risk is incurred in Centralized Alternative 5 (2.3 over a total population of 20,762 FTEs), in which all waste is treated by volume reduction at Hanford.

Estimated construction fatality risks for workers are lowest in the No Action Alternative (8.2E–01), in which no new treatment facilities are to be built. New facilities will be required at several installations in the volume reduction alternatives (Regionalized 2, 4, and 5, and Centralized 3, 4, and 5); however, the risks in these alternatives are higher than in the remaining alternatives by only a factor of two. Estimated operational fatalities are slightly higher (by about a factor of two or less) for the No Action Alternative (1.7) and the volume reduction alternatives (1.8 to 2.1) than for the minimum treatment alternatives (1.0 to 1.1). This is because more worker person-hours are required for the 20-year No Action treatment period and for the more extensive treatment in the volume reduction alternatives.

Although worker risks are very similar across alternatives, some differences in installation risks are notable. The estimated total fatalities (cancer fatalities plus construction and operational fatalities) in the No Action and minimum treatment alternatives are consistently very similar among installations (E–02 to E–01 range) except at KCP, NTS, and Pinellas (E–03 order of magnitude), which have much smaller waste loads to treat and employ fewer workers (11 to 13, 21 to 26, 64 to 108 FTES, respectively) than are needed at other installations.

By a slight margin, LANL and SRS pose the highest total worker fatality risks in the Regionalized 2, 4, and 5, and Centralized 3 and 4 volume reduction alternatives (total fatalities range from 8.3E–01 to

9.3E–01); however, the risks among installations in these alternatives are within approximately 1 order of magnitude except at KCP and Pinellas, at which worker fatality risks are 1 to 2 orders of magnitude lower in all alternatives. The slight elevation in risks at LANL and SRS in the volume-reduction alternatives reflects consolidation of waste loads at these installations for treatment, additional construction of treatment facilities, and the presence of a large number of FTEs at ORNL in these scenarios. Total fatalities also increase slightly at INEL (1.34) in Regionalized Alternative 5, in which volume reduction is performed at four installations; this is due mainly to larger consolidated waste loads in treatment and a larger exposed work force than for other alternatives. The highest estimated total fatalities are in Centralized Alternative 5 at Hanford (3.65 in 9,856 FTEs), where all volume reduction is performed and the treatment work force is greatly increased compared to other alternatives.

#### D.3.2.4.2 *Programwide Trends in Human Health Risks Associated With LLW Disposal*

For the MEL of the hypothetical farm family, the health risks associated with the LLW disposal alternatives show no discernable trends. The risk of cancer fatality to all 143 farm family lifetimes across alternatives ranges from 0.0 to 1.3 cancer fatalities over 10,000 years. Estimated cancer fatalities for workers during disposal are very similar across alternatives, ranging from 1.4 to 3.2; worker risks tend to increase as the waste load to be disposed of becomes larger and as more disposal facility construction is required.

**Maximally Exposed Lifetime of the Hypothetical Farm Family.** For each alternative, with the exception of Centralized Alternatives 2 and 4 (single site disposal at NTS), the risk of cancer incidence to the MEL of the farm family is greater than 1E–04. For the "average" individual member of the farm family, the risk of cancer incidence (determined by dividing the cancer incidence risk in Table D.3.2–3 by the number of family members, four, times the number of disposal sites for that alternative), may be considered above the target exposure level in all alternatives except Centralized 2 and 4.

The highest cancer fatality risks to the MEL are in Decentralized (in which wastes receive minimum treatment and are then disposed of at 12 installations). Estimated programwide cancer fatality risks are 6.5E–02 in Decentralized.

The lowest risks of cancer fatality to the MEL are in Centralized 2 (minimum treatment and disposal at NTS) and Centralized 4 (volume reduction at seven installations and disposal at NTS). The programwide risks of cancer fatality for the four-member farm family are 0.0 in Centralized 2 and in Centralized 4.

At the installation level, the lowest disposal risks are at LANL in the No Action, Decentralized, Regionalized 1, 2, 3, 4, and 5 Alternatives; at NTS in the No Action, Regionalized 2, 3, 4, 5, and 7, and Centralized 2 and 4 Alternatives; at Pantex in the Decentralized and Regionalized 2 Alternatives; and at INEL in the No Action, Decentralized, and Regionalized 1, 2, 3, 4, and 5 Alternatives. The estimated radiological risks at these installations are zero because the wastes being disposed of contain low concentrations of radionuclides and the migration of the contaminants into the groundwater is very slow (all four installations receive little annual rainfall).

The highest "average" disposal installation risk to a farm family member is at SNL-NM in the Decentralized Alternative (average individual risk of cancer fatality is 6.3E–02). The MEL is lifetime 15 at SNL-NM, where uranium-238 contributes over 99% of the dose received by farm family members.

**Workers Placing Wastes Into Disposal.** The estimated worker risks from disposal are very similar across alternatives, ranging from 1.4 to 3.2 for cancer fatality and 4.9 to 11 for cancer incidence. However, the estimated risk of fatality from construction is more than 1 order of magnitude lower for the one-installation disposal alternatives (the five Centralized Alternatives) than for the other alternatives. In the Centralized scenarios, Hanford and NTS are the single-disposal installations; both have large amounts of existing disposal capacity compared to other installations and, therefore, require less new construction.

The highest construction fatality risks occur in Regionalized 6 and 7; these alternatives involve two-installation disposal at Hanford and SRS and NTS and SRS, respectively. The majority of the construction-related worker risks are at SRS, which has a relatively small amount of existing disposal capacity and, based on the large amount of LLW to be sent there for disposal in these disposal scenarios, would require extensive construction.

The estimated number of operational fatalities is within 1 order of magnitude among alternatives (ranging from 2.9E–01 to 1.8). In general, operational fatalities are slightly higher for scenarios in which multiple installations dispose (the No Action, Decentralized, and Regionalized 1 and 3 Alternatives), and are slightly lower where only one installation disposes (the Centralized Alternatives). This is because the fewer the

disposal installations, the fewer the number of FTEs needed to operate them (therefore, fewer workers are around to be involved in operational accidents).

Although overall risks to workers from disposal do not differ appreciably among alternatives, some trends are apparent in the installation-specific risks associated with disposal. In the multiple-installation disposal alternatives (the No Action, Decentralized, and Regionalized Alternatives), the same four installations, Hanford, INEL, SRS, and LANL, have the highest cancer risks by approximately 0.5 to 2 orders of magnitude; all four are consolidation installations for LLW disposal in these alternatives. The controlling contaminants are cobalt-60 at Hanford, INEL, and SRS, and cesium–137 and daughter products at LANL; external radiation is the predominant exposure route. In the two-installation disposal alternatives (Hanford and SRS in Regionalized 6; NTS and SRS in Regionalized 7), Hanford and NTS cancer risks are approximately twice as high as those for disposal at SRS. The controlling contaminant for disposal at Hanford and NTS in Regionalized 6 and 7 is cobalt-60; the primary exposure route is external radiation. However, there are more estimated fatalities at SRS due to physical hazards because of the construction of new disposal facilities.

#### D.3.2.4.3 *Comparison Among Treatment Options*

For workers, comparison of minimum treatment and volume reduction scenarios shows very little difference in cancer risks associated with LLW treatment. In all alternatives, estimated worker cancer fatality risks from treatment are very similar, ranging between 8.1E–01 and 2.3. Overall, worker risks at particular installations seem to be driven primarily by waste consolidation and facility construction.

The programwide risk of cancer fatality for all of the minimum treatment alternatives are identical for all receptors. The overall risks associated with the volume reduction alternatives are approximately 0.5 to 1.5 orders of magnitude higher than the risks associated with minimum treatment only. This can be seen at the installation level as well as at the program level; for example, at RFETS, cancer fatalities in the offsite population increase from 4.0E–07 in Regionalized Alternative 5 (which involves minimum treatment) to 1.9E–04 in Regionalized Alternative 4 (which involves volume reduction). This is attributable to increased atmospheric releases associated with the incineration of LLW.

Comparison of the risks for the volume reduction alternatives shows that the risks for all receptors vary by no more than a factor of six between volume reduction at 11 installations and volume reduction at 7, 4, or 1 installation(s).

#### D.3.2.4.4 *Comparison Among Disposal Scenarios*

Comparisons can be made between the alternatives in which treatment is the same but the number of disposal sites varies from 12 installations to 1. For the minimum treatment alternatives, the cancer fatality risks to all farm family lifetimes range from 0.0 to 1.2. There are no apparent trends as the number of disposal facilities changes. The cancer fatality risks in the single-installation disposal alternatives (Centralized 1 and 2) are 0.0 at NTS and 4.8E–03 at Hanford.

Comparison of disposal risks among alternatives that have the same disposal scenarios but different treatment options shows that the type of LLW treatment has little effect on the cancer risks to all farm family lifetimes or to the MEL. For example, in the 10-installation disposal alternatives (Regionalized 1 and Regionalized 2), the major difference is that minimum treatment is performed at all installations in Regionalized 1, while additional volume reduction is performed at 11 installations in Regionalized 2. Risks of cancer fatality to all farm family lifetimes from disposal are higher in Regionalized 2 by less than a factor of four. This small difference is found for both the MEL and for all lifetimes across Regionalized 3, 4, and 5 (the six-installation disposal alternatives); Centralized 1, 3, and 5 (the alternatives in which disposal takes place at Hanford); and Centralized 2 and 4 (in which LLW is disposed of at NTS).

As previously noted for worker risks associated with LLW treatment, the disposal risks to workers do not differ appreciably among alternatives; however, certain installation-specific risks tend to be higher where waste loads are consolidated for disposal or where more construction of disposal facilities is required.

#### D.3.2.4.5 *Summary of Results for Routine Treatment and Disposal of LLW*

Treatment by volume reduction slightly increases the cancer risks to offsite and noninvolved worker populations at a particular installation in comparison to minimum treatment. However, the type of treatment does not affect the subsequent disposal risks to the farm family as much as the amount of waste consolidated

at an installation or the hydrogeology and meteorology of the disposal installation (both of which can markedly affect the migration of contaminants into groundwater). Volume reduction tends to concentrate waste, producing slightly higher estimated risks to the farm family.

In all but two disposal alternatives (Centralized 2 and 4), the programwide risks of cancer incidence to the MEL of the hypothetical farm family exceed 1E–06. Recall that this is a conservative disposal scenario in which the farm family residence and drinking water well are situated 300 m downgradient from the center of a disposal facility, and that the well serves as the sole source of water for the family, their livestock, and crops.

Worker risks are very similar across all alternatives, regardless of treatment type or disposal scenario; programwide risks are within 1 order of magnitude across all treatment alternatives and all disposal alternatives. Fatalities associated with radiation exposure are usually fewer than those due to the physical hazards of constructing and operating treatment and disposal facilities, except in the one-site disposal alternatives at NTS and Hanford. As discussed above, these installations have relatively large existing disposal facility capacities and require less construction. Overall, however, worker risks at specific installations seem to be driven primarily by the amount of waste consolidated for treatment and/or disposal and the amount of facility construction needed.

### D.3.2.5 Summary of Alternatives for Potential LLW Accidents

For LLW, health risks from potential incinerator accidents were evaluated for the No Action, Regionalized 2, and Centralized 5 Alternatives (see Section D.3.2.1); no storage-related accidents were analyzed. The types of accidents evaluated were (1) a baghouse area facility fire; (2) an earthquake leading to a fire in the incinerator facility; (3) the crash of a large aircraft (at INEL, SRS, and Hanford) or a small aircraft (at RFETS and PGDP) resulting in fire and explosion; and (4) an incinerator explosion. Accidents in "alpha facilities" (incinerators that process LLW contaminated with alpha-emitting radionuclides) were evaluated for RFETS in Regionalized 2 and for Hanford in Centralized 5.

Aircraft impacts were not evaluated for FEMP, LANL, LLNL, Mound Plant, PGDP, or ORR.

For more detailed information on accident scenarios, see Appendix F.

### D.3.2.6 Special Assumptions and Considerations Used in the LLW Accident Analysis

All accident releases from incinerator facilities to the outside (i.e., to the offsite and noninvolved worker populations) are assumed to be at ground level with dispersion starting at a lower level rather than from a facility stack. In the incinerator explosion accident scenario, it is assumed that the efficiency of the facility's high-efficiency particulate air filtration system drops to 99.9%. In the assessment of worker risks from incineration accidents, it is assumed that the air in the work area is not ventilated or filtered; the intrafacility source term for this accident is, therefore, 1,000 times higher than the atmospheric source term used to calculate risks to the offsite and noninvolved worker populations. During all accidents, one shift of waste management workers is assumed to be inside the facility. Shift size varies from one to eight workers (see Table D.3.2–64), which can be found at the end of Section D.3.2.7.

Incineration accidents are assumed to result in releases into the operating gallery where the workers are located. Half of the operating gallery (e.g., an area 32 m long × 6 m wide × 6 m high) is assumed to fill with contaminated air. Exposure duration is 1 min, the time necessary for workers to avoid any obstructions and leave the scene.

Each accident type has an associated estimated annual frequency of occurrence as determined by Argonne National Laboratory (see Section D.2.12.1). However, the probability of occurrence is not directly taken into account in the risk calculations. Risks estimates associated with each accident should be interpreted as the consequences if the accident occurred. The incinerator explosion is considered to be "anticipated" (greater than 1.0E–02 per year); the baghouse area fire is considered "unlikely" (1.0E–04 to 1.0E–02 per year); the earthquake with resulting fire is considered "very unlikely" (1.0E–06 to 1.0E–04 per year); and the aircraft impact is regarded as "extremely unlikely" (less than 1.0E–06 per year), (see Appendix F, Table F.2–2). Slightly different labels are assigned to these frequencies in Appendix F.

### D.3.2.7 Results Tables for the Risk Analysis of Potential LLW Accidents

Table D.3.2–61 presents a summary of the maximum reasonably foreseeable accident risks to the offsite and noninvolved worker populations, their respective MEIs, and waste management worker populations for treatment facility accidents, by installation and alternative. Table D.3.2–62 provides the sizes of the offsite, noninvolved worker, and worker populations at each installation. Tables D.3.2–63 through D.3.2–75 present more detailed results by health endpoint and installation.

***Table D.3.2–61. Risks From Potential Maximum Reasonably Foreseeable LLW Treatment Facility Accidents, by Alternative and Site***

| Site | Offsite Population | | Offsite MEI | | Noninvolved Worker Population | | Noninvolved Worker MEI | | Worker Population | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CF | CI | CF | CI | CF | CI | CF | CI | CF | CI |
| **No Action** | | | | | | | | | | |
| INEL | 5.9E–05 | 2.0E–04 | 6.7E–09 | 2.3E–08 | 2.2E–05 | 7.5E–05 | 1.3E–08 | 4.5E–08 | 1.5E–05 | 5.4E–05 |
| SRS | 4.6E–02 | 1.6E–01 | 1.4E–06 | 4.9E–06 | 9.6E–03 | 3.3E–02 | 4.2E–05 | 1.4E–04 | 9.5E–03 | 3.3E–02 |
| **Regionalized 2** | | | | | | | | | | |
| FEMP | 6.0E–05 | 2.1E–04 | 1.6E–08 | 5.4E–08 | 2.2E–06 | 7.6E–06 | 1.5E–08 | 5.1E–08 | 3.6E–07 | 1.3E–06 |
| Hanford | 2.4E–03 | 8.1E–03 | 5.5E–08 | 1.9E–07 | 1.2E–04 | 4.2E–04 | 1.3E–06 | 4.2E–06 | 1.0E–05 | 3.5E–05 |
| INEL | 5.9E–05 | 2.0E–04 | 6.7E–09 | 2.3E–08 | 2.2E–05 | 7.5E–05 | 1.3E–08 | 4.5E–08 | 1.9E–05 | 6.7E–05 |
| LANL | 8.7E–01 | 3.0 | 4.1E–04 | 1.4E–03 | 2.5E–01 | 8.6E–01 | 7.4E–04 | 2.5E–03 | 2.5E–01 | 8.7E–01 |
| LLNL | 2.9 | 9.8 | 4.0E–04 | 1.4E–03 | 2.1E–01 | 7.1E–01 | 3.6E–04 | 1.2E–03 | 7.3E–03 | 2.6E–02 |
| ORR | 1.3E–02 | 4.4E–02 | 1.1E–06 | 3.7E–06 | 8.8E–03 | 3.0E–02 | 9.8E–06 | 3.3E–05 | 7.8E–04 | 2.7E–03 |
| PGDP | 2.5E–04 | 8.6E–04 | 7.4E–08 | 2.5E–07 | 4.9E–05 | 1.7E–04 | 4.3E–07 | 1.5E–06 | 3.8E–05 | 1.3E–04 |
| PORTS | 2.5E–05 | 8.6E–05 | 1.7E–08 | 5.9E–08 | 1.1E–05 | 3.8E–05 | 1.7E–08 | 5.7E–08 | 5.2E–06 | 1.8E–05 |
| RFETS | 2.8E–02 | 9.4E–02 | 9.8E–07 | 3.3E–06 | 4.8E–03 | 1.6E–02 | 1.4E–05 | 4.8E–05 | 2.1E–03 | 7.3E–03 |
| SRS | 4.6E–02 | 1.6E–01 | 1.4E–06 | 4.9E–06 | 9.6E–03 | 3.3E–02 | 4.2E–05 | 1.4E–04 | 1.2E–02 | 4.1E–02 |
| **Centralized 5** | | | | | | | | | | |
| Hanford | 4.8 | 1.6E+01 | 1.1E–04 | 3.8E–04 | 9.1E–01 | 3.1 | 9.2E–03 | 3.1E–02 | 6.0E–01 | 2.1 |

Notes: MEI = maximally exposed individual; each value represents the highest *single* risk (not the sum of all risks) to the MEI from among all accidents at an installation. CF = risk of cancer fatality associated with exposure to radionuclides. CI = risk of cancer incidence associated with exposure to radionuclides.

***Table D.3.2–62. Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Potential LLW Treatment Accidents, by Site***

| Site | Offsite Population | Noninvolved Worker Population | WM Worker Population | | |
|---|---|---|---|---|---|
| | | | No Action | Regionalized 2 | Centralized 5 |
| Hanford | 377,645 | 8,674 | | 1 | 8 |
| FEMP | 2,764,589 | 2,456 | | 4 | |
| INEL | 153,061 | 8,451 | 4 | 5 | |
| LANL | 159,152 | 11,552 | | 6 | |
| LLNL | 6,324,234 | 9,504 | | 1 | |
| ORR | 881,652 | 3,809 | | 6 | |
| PGDP | 500,502 | 1,952 | | 4 | |
| PORTS | 639,602 | 3,226 | | 5 | |
| RFETS | 2,171,877 | 6,993 | | 8 | |
| SRS | 620,618 | 15,996 | 4 | 5 | |

*Table D.3.2-63. Accident Risks Associated With LLW Treatment at INEL Under the No Action Alternative, by Accident Type*

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, earthquake (VU)[b] | 3.9E-05 | 4.5E-09 | 1.0E-05 | 1.3E-04 | 1.5E-08 | 3.6E-05 |
| Incineration, incinerator explosion (A) | 2.4E-08 | 2.7E-12 | 6.1E-06 | 8.0E-08 | 9.1E-12 | 2.2E-05 |
| Incineration, baghouse area fire (U) | 5.9E-07 | 6.7E-11 | 1.5E-07 | 2.0E-06 | 2.3E-10 | 5.4E-07 |
| Incineration, large aircraft crash (EU) | 5.9E-05 | 6.7E-09 | 1.5E-05 | 2.0E-04 | 2.3E-08 | 5.4E-05 |
| Maximum reasonably foreseeable accident | 5.9E-05 | 6.7E-09 | 1.5E-05 | 2.0E-04 | 2.3E-08 | 5.4E-05 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

*Table D.3.2-64. Accident Risks Associated With LLW Treatment at SRS Under the No Action Alternative, by Accident Type*

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, large aircraft crash (EU)[b] | 4.6E-02 | 1.4E-06 | 9.5E-03 | 1.6E-01 | 4.9E-06 | 3.3E-02 |
| Incineration, earthquake (VU) | 3.1E-02 | 9.6E-07 | 6.3E-03 | 1.0E-01 | 3.3E-06 | 2.2E-02 |
| Incineration, incinerator explosion (A) | 1.8E-05 | 5.8E-10 | 3.8E-03 | 6.2E-05 | 2.0E-09 | 1.3E-02 |
| Incineration, baghouse area fire (U) | 4.6E-04 | 1.4E-08 | 9.5E-05 | 1.6E-03 | 4.9E-08 | 3.3E-04 |
| Maximum reasonably foreseeable accident | 4.6E-02 | 1.4E-06 | 9.5E-03 | 1.6E-01 | 4.9E-06 | 3.3E-02 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

***Table D.3.2–65. Accident Risks Associated With LLW Treatment at FEMP Under Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, earthquake (VU)[b] | 6.0E–05 | 1.6E–08 | 3.6E–07 | 2.1E–04 | 5.4E–08 | 1.3E–06 |
| Incineration, incinerator (A) explosion | 3.6E–08 | 9.5E–12 | 2.1E–07 | 1.2E–07 | 3.2E–11 | 7.5E–07 |
| Incineration, baghouse area (U) fire | 9.1E–07 | 2.4E–10 | 5.4E–09 | 3.1E–06 | 8.1E–10 | 1.9E–08 |
| Maximum reasonably foreseeable accident | 6.0E–05 | 1.6E–08 | 3.6E–07 | 2.1E–04 | 5.4E–08 | 1.3E–06 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (> 1E–02), "U" for unlikely (1E–04 to 1E–02), "VU" for very unlikely (1E–06 to 1E–04), and "EU" for extremely unlikely (< 1E–06).

***Table D.3.2–66. Accident Risks Associated With LLW Treatment at Hanford Under Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, earthquake (VU)[b] | 1.6E–03 | 3.7E–08 | 6.7E–06 | 5.4E–03 | 1.3E–07 | 2.3E–05 |
| Incineration, incinerator (A) explosion | 9.5E–07 | 2.2E–11 | 4.0E–06 | 3.2E–06 | 7.5E–11 | 1.4E–05 |
| Incineration, baghouse area (U) fire | 2.4E–05 | 5.5E–10 | 1.0E–07 | 8.1E–05 | 1.9E–09 | 3.5E–07 |
| Incineration, large (EU) aircraft crash | 2.4E–03 | 5.5E–08 | 1.0E–05 | 8.1E–03 | 1.9E–07 | 3.5E–05 |
| Maximum reasonably foreseeable accident | 2.4E–03 | 5.5E–08 | 1.0E–05 | 8.1E–03 | 1.9E–07 | 3.5E–05 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (> 1E–02), "U" for unlikely (1E–04 to 1E–02), "VU" for very unlikely (1E–06 to 1E–04), and "EU" for extremely unlikely (< 1E–06).

***Table D.3.2–67. Accident Risks Associated With LLW Treatment at INEL Under Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, large aircraft crash (EU)[b] | 5.9E–05 | 6.7E–09 | 1.9E–05 | 2.0E–04 | 2.3E–08 | 6.7E–05 |
| Incineration, earthquake (VU) | 3.9E–05 | 4.5E–09 | 1.3E–05 | 1.3E–04 | 1.5E–08 | 4.5E–05 |
| Incineration, incinerator explosion (A) | 2.4E–08 | 2.7E–12 | 7.7E–06 | 8.0E–08 | 9.1E–12 | 2.7E–05 |
| Incineration, baghouse area fire (U) | 5.9E–07 | 6.7E–11 | 1.9E–07 | 2.0E–06 | 2.3E–10 | 6.7E–07 |
| Maximum reasonably foreseeable accident | 5.9E–05 | 6.7E–09 | 1.9E–05 | 2.0E–04 | 2.3E–08 | 6.7E–05 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E–02), "U" for unlikely (1E–04 to 1E–02), "VU" for very unlikely (1E–06 to 1E–04), and "EU" for extremely unlikely (<1E–06).

***Table D.3.2–68. Accident Risks Associated With LLW Treatment at LLNL Under Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, earthquake (VU)[b] | 2.9 | 4.0E–04 | 7.3E–03 | 9.8 | 1.4E–03 | 2.6E–02 |
| Incineration, incinerator explosion (A) | 1.7E–03 | 2.4E–07 | 4.4E–03 | 5.9E–03 | 8.1E–07 | 1.5E–02 |
| Incineration, baghouse area fire (U) | 4.3E–02 | 6.0E–06 | 1.1E–04 | 1.5E–01 | 2.0E–05 | 3.8E–04 |
| Maximum reasonably foreseeable accident | 2.9 | 4.0E–04 | 7.3E–03 | 9.8 | 1.4E–03 | 2.6E–02 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E–02), "U" for unlikely (1E–04 to 1E–02), "VU" for very unlikely (1E–06 to 1E–04), and "EU" for extremely unlikely (<1E–06).

***Table D.3.2-69. Accident Risks Associated With LLW Treatment at LANL Under Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, earthquake (VU)[b] | 8.7E-01 | 4.1E-04 | 2.5E-01 | 3.0 | 1.4E-03 | 8.7E-01 |
| Incineration, incinerator explosion (A) | 5.2E-04 | 2.5E-07 | 1.5E-01 | 1.8E-03 | 8.4E-07 | 5.2E-01 |
| Incineration, baghouse area fire (U) | 1.3E-02 | 6.2E-06 | 3.7E-03 | 4.4E-02 | 2.1E-05 | 1.3E-02 |
| Maximum reasonably foreseeable accident | 8.7E-01 | 4.1E-04 | 2.5E-01 | 3.0 | 1.4E-03 | 8.7E-01 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

***Table D.3.2-70. Accident Risks Associated With LLW Treatment at ORR Under Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, earthquake (VU)[b] | 1.8E-02 | 1.1E-06 | 7.8E-04 | 4.4E-02 | 3.7E-06 | 2.7E-03 |
| Incineration, incinerator explosion (A) | 7.7E-06 | 6.4E-10 | 4.7E-04 | 2.6E-05 | 2.2E-09 | 1.6E-03 |
| Incineration, baghouse area fire (U) | 1.7E-06 | 1.4E-10 | 1.0E-07 | 5.6E-06 | 4.7E-10 | 3.5E-07 |
| Maximum reasonably foreseeable accident | 1.3E-02 | 1.1E-06 | 7.8E-04 | 4.4E-02 | 3.7E-06 | 2.7E-03 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

*Table D.3.2–71. Accident Risks Associated With LLW Treatment at PGDP Under Regionalized Alternative 2, by Accident Type*

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, earthquake (VU)[b] | 2.5E–04 | 7.4E–08 | 3.8E–05 | 8.6E–04 | 2.5E–07 | 1.3E–04 |
| Incineration, incinerator explosion (A) | 1.5E–07 | 4.4E–11 | 2.3E–05 | 5.2E–07 | 1.5E–10 | 7.9E–05 |
| Incineration, baghouse area fire (U) | 3.8E–06 | 1.1E–09 | 5.6E–07 | 1.3E–05 | 3.8E–09 | 2.0E–06 |
| Incineration, small aircraft crash (EU) | 6.3E–05 | 1.8E–08 | 9.4E–06 | 2.2E–04 | 6.3E–08 | 3.3E–05 |
| Maximum reasonably foreseeable accident | 2.5E–04 | 7.4E–08 | 3.8E–05 | 8.6E–04 | 2.5E–07 | 1.3E–04 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E–02), "U" for unlikely (1E–04 to 1E–02), "VU" for very unlikely (1E–06 to 1E–04), and "EU" for extremely unlikely (<1E–06).

*Table D.3.2–72. Accident Risks Associated With LLW Treatment at PORTS Under Regionalized Alternative 2, by Accident Type*

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, baghouse area fire (U)[b] | 3.8E–07 | 2.6E–10 | 7.8E–08 | 1.3E–06 | 8.8E–10 | 2.7E–07 |
| Incineration, earthquake (VU) | 2.5E–05 | 1.7E–08 | 5.2E–06 | 8.6E–05 | 5.9E–08 | 1.8E–05 |
| Incineration, incinerator explosion (A) | 1.5E–08 | 1.0E–11 | 3.1E–06 | 5.1E–08 | 3.5E–11 | 1.1E–05 |
| Maximum reasonably foreseeable accident | 2.5E–05 | 1.7E–08 | 5.2E–06 | 8.6E–05 | 5.9E–08 | 1.8E–05 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E–02), "U" for unlikely (1E–04 to 1E–02), "VU" for very unlikely (1E–06 to 1E–04), and "EU" for extremely unlikely (<1E–06).

***Table D.3.2–73. Accident Risks Associated With LLW Treatment at RFETS Under Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, small aircraft crash (alpha) (EU)[b] | 6.9E–03 | 2.5E–07 | 5.2E–04 | 2.4E–02 | 8.3E–07 | 1.8E–03 |
| Incineration, baghouse area fire (alpha) (U) | 4.2E–04 | 1.5E–08 | 3.1E–05 | 1.4E–03 | 5.0E–08 | 1.1E–04 |
| Incineration, earthquake (alpha) (VU) | 2.8E–02 | 9.8E–07 | 2.1E–03 | 9.4E–02 | 3.3E–06 | 7.3E–03 |
| Incineration, incinerator explosion (alpha) (A) | 1.7E–05 | 5.9E–10 | 1.3E–03 | 5.7E–05 | 2.0E–09 | 4.4E–03 |
| Maximum reasonably foreseeable accident | 2.8E–02 | 9.8E–07 | 2.1E–03 | 9.4E–02 | 3.3E–06 | 7.3E–03 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E–02), "U" for unlikely (1E–04 to 1E–02), "VU" for very unlikely (1E–06 to 1E–04), and "EU" for extremely unlikely (<1E–06).

***Table D.3.2–74. Accident Risks Associated With LLW Treatment at SRS Under Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|
| | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, large aircraft crash (EU)[b] | 4.6E–02 | 1.4E–06 | 1.2E–02 | 1.6E–01 | 4.9E–06 | 4.1E–02 |
| Incineration, earthquake (VU) | 3.1E–02 | 9.6E–07 | 7.9E–03 | 1.0E–01 | 3.3E–06 | 2.8E–02 |
| Incineration, incinerator explosion (A) | 1.8E–05 | 5.8E–10 | 4.7E–03 | 6.2E–05 | 2.0E–09 | 1.7E–02 |
| Incineration, baghouse area fire (U) | 4.6E–04 | 1.4E–08 | 1.2E–04 | 1.6E–03 | 4.9E–08 | 4.1E–04 |
| Maximum reasonably foreseeable accident | 4.6E–02 | 1.4E–06 | 1.2E–02 | 1.6E–01 | 4.9E–06 | 4.1E–02 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E–02), "U" for unlikely (1E–04 to 1E–02), "VU" for very unlikely (1E–06 to 1E–04), and "EU" for extremely unlikely (<1E–06).

***Table D.3.2–75. Accident Risks Associated With LLW Treatment at Hanford Under Centralized Alternative 5, by Accident Type***

| Accident | | Cancer Fatalities[a] | | | Cancer Incidence[a] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Incineration, large aircraft crash (non-alpha) | (EU)[b] | 4.8 | 1.1E–04 | 6.0E–01 | 1.6E+01 | 3.8E–04 | 2.1 |
| Incineration, large aircraft crash (alpha) | (EU) | 2.4E–02 | 5.6E–07 | 3.1E–03 | 8.0E–02 | 1.9E–06 | 1.1E–02 |
| Incineration, earthquake (nonalpha) | (VU) | 3.2 | 7.5E–05 | 4.0E–01 | 1.1E+01 | 2.5E–04 | 1.4 |
| Incineration, earthquake (alpha) | (VU) | 1.6E–02 | 3.7E–07 | 2.1E–03 | 5.4E–02 | 1.3E–06 | 7.3E–03 |
| Incineration, incinerator explosion (nonalpha) | (A) | 1.9E–03 | 4.5E–08 | 2.4E–01 | 6.5E–03 | 1.5E–07 | 8.5E–01 |
| Incineration, incinerator explosion (alpha) | (A) | 9.5E–06 | 2.2E–10 | 1.3E–03 | 3.2E–05 | 7.6E–10 | 4.4E–03 |
| Incineration, baghouse area fire (nonalpha) | (U) | 4.8E–02 | 1.1E–06 | 6.0E–03 | 1.6E–01 | 3.8E–06 | 2.1E–02 |
| Incineration, baghouse area fire (alpha) | (U) | 2.4E–04 | 5.6E–09 | 3.1E–05 | 8.0E–04 | 1.9E–08 | 1.1E–04 |
| Maximum reasonably foreseeable accident | | 4.8 | 1.1E–04 | 6.0E–01 | 1.6E+01 | 3.8E–04 | 2.1 |

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E–02), "U" for unlikely (1E–04 to 1E–02), "VU" for very unlikely (1E–06 to 1E–04), and "EU" for extremely unlikely (<1E–06).

### D.3.2.8 Summary of the LLW Accident Analysis Results

For all receptors, the dominating accidents are those involving a large airplane crash or an earthquake during incineration (nonalpha). At any installation where both of these accident types are analyzed, the risks associated with them differ by less than a factor of two for offsite and noninvolved worker populations, offsite and noninvolved worker MEIs, and workers. The risks to all receptors from alpha facility accidents are generally lower than the comparable nonalpha facility accident risks at a given installation by about 2 orders of magnitude. This is due to a much smaller inventory of alpha LLW and therefore, much smaller releases associated with alpha incinerator accidents. Note that for workers, the risk of death from latent cancers due to exposure to radioactive materials released in such accidents may be smaller than the risk of fatality due to nonradiological impacts.

#### D.3.2.8.1 *Risks to the Offsite Population From LLW Accidents*

The lowest installation-specific health risks associated with accidents are for the incinerator explosion at INEL in No Action and Regionalized 2 (2.4E–08 cancer fatalities) and for the same accident at FEMP (3.6E–03 cancer fatalities) and PORTS (1.5E–08 cancer fatalities) in Regionalized 2. The highest accident risks are at Hanford in Centralized 5 for the large airplane crash scenario (4.8 cancer fatalities) and for the earthquake scenario (3.2 cancer fatalities) and at LLNL and LANL in Regionalized 2 for the earthquake during incineration (2.9 and 8.7E–01 cancer fatalities, respectively). The comparatively high risks to these populations are due to the combination of population distribution and waste inventory at each installation. The cancer fatality risk from the maximum reasonably foreseeable accident at Hanford in Centralized 5 increases about 3 orders of magnitude compared to that in Regionalized 2 due to waste consolidation.

In general, the airplane crash (small and large) and the earthquake with subsequent fire are the worst-case accidents in all alternatives and vary by less than 1 order of magnitude at all sites where both accident types are postulated. The associated annual frequencies for these accidents differ somewhat in that an airplane crash is considered "extremely unlikely" (less than 1.0E–06 per year) and an earthquake is considered "very unlikely" (1.0E–06 to 1.0E–04 per year).

The principal contributors to risk are uranium-238 at FEMP, Hanford (Centralized 5), LANL, PGDP, PORTS, and SRS; thorium-232 at LLNL and ORR; cesium-137 at Hanford (Regionalized 2); cobalt-60 at INEL; and plutonium-238 at Hanford (alpha incineration only in Centralized 5) and RFETS. The primary exposure route is internal exposure in all alternatives.

#### D.3.2.8.2 *Risks to the Noninvolved Worker Population From LLW Accidents*

Noninvolved worker risks are slightly lower than offsite population risks, but are distributed over a much smaller affected population. The general trend in risks by accident type, dominating accident type, controlling contaminants and exposure route, and highest-risk sites are the same as for offsite population.

#### D.3.2.8.3 *Risks to the Maximally Exposed Noninvolved Worker and Maximally Exposed Offsite Individual From LLW Accidents*

Radiological risks to the offsite and noninvolved worker MEIs generally parallel the trends for their respective populations but are 2 to 5 orders of magnitude lower. For the noninvolved worker MEI, the highest cancer fatality risks are at Hanford in Centralized 5 (9.2E–03) and at LLNL and LANL in Regionalized 2 (3.6E–04 and 7.4E–04, respectively). The highest cancer fatality risks to the offsite MEI are at LLNL and LANL in Regionalized 2 (4.0E–04 and 4.1E–04, respectively) and at Hanford in Centralized 5 (1.1E–04). The cancer risks to the offsite population in Regionalized 2 are among the highest primarily because of the relatively large contaminant releases in the accidents at LANL and LLNL combined with the relatively large number of residents living very close to each of these sites (ORNL, 1995d). The cancer risks in Centralized 5 are among the highest primarily because of the large volume of waste consolidated at Hanford (higher than the cancer risks to MEIs in Regionalized 2 by almost 4 orders of magnitude).

Controlling contaminants for both MEIs at these three sites are the same as for their respective populations, uranium-238 at LANL and Hanford and thorium-232 at LLNL. The exposure route is internal exposure for both receptors at all sites.

### D.3.2.8.4 *Risks to Waste Management Workers From LLW Accidents*

The cancer fatality risks to workers from maximum reasonably foreseeable accidents range from 3.6E–07 to 6.0E–01; shift size varies from one to eight workers. In all alternatives, the large aircraft crash into an incinerator and an earthquake at an incinerator are the highest-risk accidents. For any installation where both of these accident types were analyzed, the difference in risks between them is less than a factor of two. The next highest accident risks to workers are associated with the incinerator explosion scenario. (If the large aircraft crash is not postulated for an installation, then the earthquake and incinerator explosion scenarios are the highest-risk accident types; cancer risks differ by less than a factor of two for these two scenarios.) Risks from the baghouse fire scenario are generally 1 or more orders of magnitude lower than those associated with the aircraft crash, earthquake, and incinerator explosion scenarios. The accident types that result in higher risks to workers involve larger releases of radionuclides than the baghouse fire scenario. Recall that the estimated annual frequency of the aircraft crash accidents occurring is "extremely unlikely" (less than 1.0E–06 per year); the earthquake scenario is considered "very unlikely" (1.0E–06 to 1.0E–04 per year); the baghouse fire is considered "unlikely" (1.0E–04 to 1.0E–02 per year); and the incinerator explosion is "anticipated" (greater than 1.0E–02 per year).

The highest worker cancer fatality risk is for the maximum reasonably foreseeable accident at Hanford in Centralized 5. The cancer fatality risk at Hanford in Centralized 5 is about 5 orders of magnitude higher than at Hanford in Regionalized 2 due to the consolidation of LLW for treatment at Hanford (which would result in a larger release in the event of an accident). Exposure to uranium-238 via inhalation is the risk driver at Hanford in Centralized 5. The highest-risk sites in No Action and Regionalized 2 are SRS and LANL (Regionalized 2 only). Worker cancer fatality risks at the other sites are lower by 1 to 6 orders of magnitude. Inhalation of uranium-238 is also the driving contributor to worker risk at SRS and LANL in No Action and Regionalized 2.

### D.3.2.9 Risks to the Hypothetical Intruder From LLW Disposal

The health risks to the hypothetical intruder who drills a well through an LLW disposal facility were evaluated for the Decentralized, Regionalized 3, and Centralized 1 Alternatives, for intrusion 100 years and 300 years after the cessation of disposal activities at each installation. Tables D.3.2–76 and D.3.2–77 present summaries of the risk evaluations at 100 and 300 years, respectively. Tables D.3.2–78 through D.3.2–83 contain the health risks by health endpoint and installation for each alternative in both time frames.

***Table D.3.2–76. Summary Table for the Intruder Scenario for LLW (100 years)***

| Alternative | Radionuclides | | | |
|---|---|---|---|---|
| | Dose (rem) | Cancer Fatality | Cancer Incidence | Genetic Effects |
| Decentralized | 160 | 8.0E–02 | 2.7E–01 | 1.6E–02 |
| Regionalized 3 | 110 | 5.3E–02 | 1.8E–01 | 1.1E–02 |
| Centralized 1 | 1.7 | 8.3E–03 | 2.8E–02 | 1.7E–03 |

***Table D.3.2–77. Summary Table for the Intruder Scenario for LLW (300 years)***

| Alternative | Radionuclides | | | |
|---|---|---|---|---|
| | Dose (rem) | Cancer Fatality | Cancer Incidence | Genetic Effects |
| Decentralized | 1.7 | 8.4E–04 | 2.8E–03 | 1.7E–04 |
| Regionalized 3 | 1.1 | 5.7E–04 | 1.9E–03 | 1.1E–04 |
| Centralized 1 | 1.7E–01 | 8.4E–05 | 2.9E–04 | 1.7E–05 |

***Table D.3.2–78. Intruder Scenario Risk Results for the Decentralized Alternative (100 years)***

| Site | Radionuclides | | | |
|---|---|---|---|---|
| | Dose (rem) | Cancer Fatality | Cancer Incidence | Genetic Effects |
| ANL-E | 6.6E–01 | 3.3E–04 | 1.1E–03 | 6.6E–05 |
| Hanford | 6.8 | 3.4E–03 | 1.2E–02 | 6.8E–04 |
| INEL | 7.0E–01 | 3.5E–04 | 1.2E–03 | 7.0E–05 |
| LANL | 142 | 7.1E–02 | 2.4E–01 | 1.4E–02 |
| LLNL | 5.8 | 2.9E–03 | 9.8E–03 | 5.8E–04 |
| ORR | 1.3 | 6.6E–04 | 2.2E–03 | 1.3E–04 |
| PGDP | 6.7E–03 | 3.3E–06 | 1.1E–05 | 6.7E–07 |
| Pantex | 5.2E–03 | 2.6E–06 | 8.9E–06 | 5.2E–07 |
| PORTS | 4.8E–01 | 2.4E–04 | 8.2E–04 | 4.8E–05 |
| RFETS | 2.4E–03 | 1.2E–06 | 4.1E–06 | 2.4E–07 |
| SNL-NM | 1.5 | 7.3E–04 | 2.5E–03 | 1.5E–04 |
| SRS | 2.3 | 1.2E–03 | 4.0E–03 | 2.3E–04 |
| Total | 160 | 8.0E–02 | 2.7E–01 | 1.6E–02 |

***Table D.3.2–79. Intruder Scenario Risk Results for the Decentralized Alternative (300 years)***

| Site | Radionuclides | | | |
|---|---|---|---|---|
| | Dose (rem) | Cancer Fatality | Cancer Incidence | Genetic Effects |
| ANL-E | 7.6E–03 | 3.8E–06 | 1.3E–05 | 7.6E–07 |
| Hanford | 5.8E–02 | 2.9E–05 | 9.9E–05 | 5.8E–06 |
| INEL | 1.3E–01 | 6.6E–05 | 2.2E–04 | 1.3E–05 |
| LANL | 1.2 | 5.9E–04 | 2.0E–03 | 1.2E–04 |
| LLNL | 1.0E–01 | 5.0E–05 | 1.7E–04 | 1.0E–05 |
| ORR | 1.1E–02 | 5.3E–06 | 1.8E–05 | 1.1E–06 |
| PGDP | 6.6E–03 | 3.3E–06 | 1.1E–05 | 6.6E–07 |
| Pantex | 5.2E–03 | 2.6E–06 | 8.9E–06 | 5.2E–07 |
| PORTS | 1.2E–01 | 6.0E–05 | 2.0E–04 | 1.2E–05 |
| RFETS | 1.9E–03 | 9.5E–07 | 3.2E–06 | 1.9E–07 |
| SNL-NM | 2.6E–02 | 1.3E–05 | 4.4E–05 | 2.6E–06 |
| SRS | 2.6E–02 | 1.3E–05 | 4.5E–05 | 2.6E–06 |
| Total | 1.7 | 8.4E–04 | 2.8E–03 | 1.7E–04 |

*Table D.3.2–80. Intruder Scenario Risk Results for Regionalized Alternative 3 (100 years)*

| Site | Radionuclides | | | |
|---|---|---|---|---|
| | Dose (rem) | Cancer Fatality | Cancer Incidence | Genetic Effects |
| Hanford | 6.8 | 3.4E–03 | 1.2E–02 | 6.8E–04 |
| INEL | 7.0E–01 | 3.5E–04 | 1.2E–03 | 7.0E–05 |
| LANL | 91 | 4.5E–02 | 1.5E–01 | 9.1E–03 |
| NTS | 5.8 | 2.9E–03 | 9.8E–03 | 5.8E–04 |
| ORR | 8.1E–01 | 4.1E–04 | 1.4E–03 | 8.1E–05 |
| SRS | 2.3 | 1.2E–03 | 4.0E–03 | 2.3E–04 |
| Total | 110 | 5.3E–02 | 1.8E–01 | 1.1E–02 |

*Table D.3.2–81. Intruder Scenario Risk Results for Regionalized Alternative 3 (300 years)*

| Site | Radionuclides | | | |
|---|---|---|---|---|
| | Dose (rem) | Cancer Fatality | Cancer Incidence | Genetic Effects |
| Hanford | 5.8E–02 | 2.9E–05 | 9.9E–05 | 5.8E–06 |
| INEL | 1.3E–01 | 6.6E–05 | 2.2E–04 | 1.3E–05 |
| LANL | 7.6E–01 | 3.8E–04 | 1.3E–03 | 7.6E–05 |
| NTS | 1.0E–01 | 5.0E–05 | 1.7E–04 | 1.0E–05 |
| ORR | 6.1E–02 | 3.0E–05 | 1.0E–04 | 6.1E–06 |
| SRS | 2.6E–02 | 1.3E–05 | 4.5E–05 | 2.6E–06 |
| Total | 1.1 | 5.7E–04 | 1.9E–03 | 1.1E–04 |

*Table D.3.2–82. Intruder Scenario Risk Results for Centralized Alternative 1 (100 years)*

| Site | Radionuclides | | | |
|---|---|---|---|---|
| | Dose (rem) | Cancer Fatality | Cancer Incidence | Genetic Effects |
| Hanford | 1.7 | 8.3E–03 | 2.8E–02 | 1.7E–03 |
| Total | 1.7 | 8.3E–03 | 2.8E–02 | 1.7E–03 |

*Table D.3.2–83. Intruder Scenario Risk Results for Centralized Alternative 1 (300 years)*

| Site | Radionuclides | | | |
|---|---|---|---|---|
| | Dose (rem) | Cancer Fatality | Cancer Incidence | Genetic Effects |
| Hanford | 1.7E–01 | 8.4E–05 | 2.9E–04 | 1.7E–05 |
| Total | 1.7E–01 | 8.4E–05 | 2.9E–04 | 1.7E–05 |

### D.3.2.9.1 *Results of the Human Health Risk Analysis for the Intruder*

In the Decentralized Alternative, LLW is disposed of at 12 sites. One hundred years after the end of disposal operations, the highest intruder cancer fatality risk is at LANL (7.1E–02). This is due to both the large volume of waste disposed at LANL in this alternative and the presence of strontium-90 in the inventory. Strontium is a bone-seeking radionuclide; hence, its internal dose conversion factors are high.

The lowest intruder cancer fatality risk is at RFETS (1.2E–06), which disposes of only its own waste in this alternative. Three hundred years after disposal operations end, the highest and lowest intruder risks are still at LANL (5.9E–04) and RFETS (9.5E–07), respectively; strontium-90 continues to be the driving contaminant at LANL. In the Regionalized Alternative 3, LLW is consolidated and disposed of at six sites. One hundred years after the completion of disposal operations, the highest intruder cancer fatality risk is at LANL (4.5E–02). Again, this is due to the large volume of waste that is disposed of and the presence of strontium-90 in the inventory. In Regionalized 3, LANL receives waste from SNL-NM, Pantex, and RFETS. The lowest intruder cancer fatality risk is at INEL (3.5E–04), which disposes of only its own waste. Three hundred years after the end of disposal operations, the highest intruder cancer fatality risk remains at LANL (3.8E–04). The lowest intruder cancer fatality risk is at SRS (1.3E–05), which receives waste from Pinellas. INEL is no longer the lowest-risk installation because of the accumulation of higher-risk daughter (radioactive decay) products at this installation during the intervening 200 years.

In the Centralized Alternative 1, all LLW is consolidated and disposed of at Hanford. One hundred years after disposal operations end, the intruder's risk of cancer fatality is 8.3E–03. Three hundred years after disposal operations, the risks are 2 orders of magnitude lower.

Overall, Centralized 1 results in the lowest collective risks to the intruder among the three alternatives. This result may seem counterintuitive. However, when relatively low-activity wastes from other sites are added to the higher-activity Hanford wastes, the resulting *average* waste concentration at Hanford is lower than in Decentralized and Regionalized 3. Consequently, the risks to the intruder are lowest in Centralized 1.

### D.3.3 HAZARDOUS WASTE

Hazardous waste (HW) is broadly defined in the Resource Conservation and Recovery Act (RCRA) as a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may: (1) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or (2) pose a substantial or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

The EPA has more specifically defined and identified HW according to considerations such as acute and chronic toxicity, persistence, and degradability in nature; potential for bioaccumulation; and other characteristics such as ignitability, corrosiveness, and reactivity. Based on these factors, the EPA promulgated regulations under 40 CFR 261, classifying HW as "listed" waste, "characteristic" waste, or "other" waste. Listed wastes are those specifically identified on one of the lists in 40 CFR 261, Subpart D. These include wastes from nonspecific sources, wastes from specific sources or industries, and a rigidly defined list of commercial chemical products. Examples of listed wastes are spent solvents, spent sludges, and discarded commercial chemicals such as cyanides, benzene, and chloroform. Characteristic wastes are defined by 40 CFR 261, Subpart C, as exhibiting ignitability, corrosiveness, reactivity, or toxicity. Other HW includes mixtures that contain HW and residues from HW treatment. HW contains no radioactive component; wastes that meet the RCRA definition of HW and are also radioactive are addressed as low-level mixed waste (see Section D.3.5).

HW is generated by a variety of DOE activities including those associated with defense, nuclear energy, and energy research programs. The following 11 sites generate the majority of the DOE inventory of HW and are considered in this human health risk evaluation (note that the abbreviations given here are used throughout this appendix):

- Argonne National Laboratory-East (ANL-E), Argonne, Illinois
- Hanford Site (Hanford), Richland, Washington
- Fermi National Accelerator Laboratory (Fermi), Batavia, Illinois
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Kansas City Plant (KCP), Kansas City, Missouri
- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Lawrence Livermore National Laboratory (LLNL), Livermore, California

- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee
- Pantex Plant (Pantex), Amarillo, Texas
- Sandia National Laboratories-New Mexico (SNL-NM), Albuquerque, New Mexico
- Savannah River Site (SRS), Aiken, South Carolina

The quantities and types of HW generated vary throughout the DOE complex. Laboratory facilities generate wastes (e.g., laboratory solutions, acids, and caustics) as a result of research and development activities, processing operations, and other activities associated with their mission. Production facilities generate HW as a result of manufacturing weapons and weapons materials, nuclear fuel, and other production operations. Many sites also generate reportable quantities of industrial solvents, paints, oils, rags, and wipes contaminated with hazardous cleaning compounds, and other hazardous materials that are byproducts of routine maintenance, degreasing, and machine-shop operations (ANL, 1996d). The current HW management strategy is based on minimizing (or eliminating) HW generation, and on proper characterization, treatment, and disposal.

Environmental restoration activities also contribute substantially to HW generation. While an installation may produce very little HW in the course of routine operations, remediation of environmental problems such as leaking petroleum underground storage tanks may generate thousands of pounds of HW-contaminated soil.

For more detailed information on HW, including HW inventories at DOE sites, estimated release rates, treatment categories used in the PEIS, and the process for developing PEIS HW alternatives, see Chapters 3 and 10 of the PEIS and the HW technical report (ANL, 1996d).

### D.3.3.1 Summary of HW Alternatives

The PEIS waste management alternatives (No Action, Regionalized 1 and 2) and the rationale for developing the various HW analysis alternatives are discussed rigorously in the main body of the PEIS.

- The No Action Alternative demonstrates the baseline risks of treating some of the DOE inventory of HW by incineration only (no waste fuel burning) at existing facilities at INEL and the ORR, while the remainder is treated by permitted commercial facilities.

- In the Regionalized Alternative 1, approximately 50% of the complexwide, commercially treated HW is instead treated by incineration and waste fuel burning at Hanford, INEL, LANL, ORR, and SRS. The remaining HW is treated and disposed of by permitted commercial facilities.
- In the Regionalized Alternative 2, approximately 80% to 90% of the complexwide, commercially treated HW is instead treated by incineration and waste fuel burning at INEL and ORR. The remainder is treated and disposed of by a limited number of permitted commercial facilities.

Table D.3.3–1 presents the consolidation and treatment schemes for these three alternatives.

Note that Section 10.3 of Volume I describes a Decentralized Alternative for HW management. The main difference between the No Action and Decentralized Alternatives is a 6% shift in the waste totals for thermal treatment and fuel substitution from offsite treatment, under the No Action Alternative, to onsite treatment, under the Decentralized Alternative. Because of this relatively small difference, the potential impacts of these two alternatives are expected to be quite similar. Therefore, health risk estimates for the Decentralized Alternative are not presented in this section of the WM PEIS. However, Section 10.4 of Volume I and the Volume II site data tables include risk estimates for the Decentralized Alternative, which are the same as those presented for the No Action Alternative.

### D.3.3.2 Special Assumptions and Considerations Used in the HW Risk Analysis

The source term for chlorinated organics and inorganics emitted in incinerator flue gases was developed from a set of RCRA trial burn data from the Rollins Deer Park, Texas, waste incinerator (one of the commercial facilities that currently processes DOE-generated HW); the constituents in the flue gases are shown in Table D.3.3–2. Although the chemistry of the industrial wastes used in the trial burn was unknown, they were waste types generally typical of DOE HW and were assumed to be reasonably similar to DOE HW in organic composition (ANL, 1996d). The results of those burns were scaled up based on each installation's HW waste volume.

It was assumed that the composition of HW and the relative proportions of its components are the same at all sites. Because of this, the controlling contaminants and their percentage contribution to risk are the same across all sites and alternatives.

***Table D.3.3–1. PEIS Alternatives for HW***

| Alternative | ANL-E | Hanford | Fermi | INEL | KCP | LANL | LLNL | ORR | Pantex | SNL-NM | SRS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action— Treatment of own HW (by incineration) at current 2 sites; remainder treated commercially | | | | T | | | | T | | | |
| Regionalized 1— 50% of DOE HW treated (by incineration and fuel burning) at 5 sites; remainder treated commercially | | T | | T | | T | | T | | | T |
| Regionalized 2— 80-90% of DOE HW treated (by incineration and fuel burning) at 2 sites; remainder treated commercially | | | | T | | | | T | | | |

Note: T = treatment installation.

***Table D.3.3–2 HW Source Term Constituents Derived From Analysis of Deer Park, Texas, Incinerator Flue Gases***

| Constituents in HW Source Term | |
|---|---|
| Bromodichloromethane | Chlorine |
| Chlorobenzene | Vinyl chloride |
| Chloromethane | Cadmium |
| Chloroform | Chromium (VI) |
| Dibromochloromethane | Copper |
| 1,2-Dichloroethane | Lead |
| Methylene chloride | Mercury |
| 1,1,2,2-Tetrachloroethane | Nickel |
| 1,1,1-Trichloroethane | Zinc |
| 1,1,2-Trichloroethane | Arsenic |
| Trichlorofluoromethane | Dioxins (PCDD) |
| Hydrogen chloride | Furans (PCDF) |

Consistent with the other waste streams, the duration of the No Action Alternative is assumed to be 20 years. For the Regionalized 1 and 2 Alternatives, construction of treatment facilities is assumed to take place for 10 years and HW treatment for 10 years.

The RfDs/RfCs and cancer potency factors for the various HW constituents, where available, were obtained from the EPA's Health Effects Assessment Summary Tables and Integrated Risk Information System. If the EPA values were not available, toxicity values derived by PNL were used (Droppo et al., 1989).

It was assumed that an FTE (see Section D.2) would not be exposed to concentrations of hazardous chemicals that exceed the time-weighted average threshold limit value (TWA-TLV) for full-time workers exposed 8 hours/day, 40 hours/week (ACGIH, 1992).

The chemicals used as surrogates in evaluating the health effects to the public from polychlorinated dibenzo-dioxins and polychlorinated dibenzofurans were hexachlorodibenzo-p-dioxin and hexachlorodibenzofuran, respectively. Due to the lack of better information, it was also assumed that the chromium in the source term was present as 100% chromium (VI), an inhalation carcinogen. This is a conservative assumption; therefore, health risks associated with chromium in the HW source term may be overestimated.
No TLVs or immediately-dangerous-to-life-and-health (IDLH) values were found for bromodichloro-methane, dibromochloromethane, hexachlorodibenzofuran, or hexachlorodibenzo-p-dioxin; therefore, the health effects to workers associated with these chemicals were not evaluated. However, the first two compounds comprise only 0.01% each of the source term, the third is 2.6E–05% of the source term, and the fourth is 3E–06% of the source term. The offsite and noninvolved worker populations were evaluated for all chemicals in the source term.

Note that the human health risks for commercial treatment are not addressed in this analysis. Therefore, the greater the percentage of waste treated commercially, the lower the human health risk estimates for the DOE complex and the less information this analysis can supply about the overall risks to human health from combined public and private HW waste management activities.

### D.3.3.3 Results Tables for the HW Human Health Risk Analysis

This section contains the results tables for the HW human health risk analysis. A discussion of the results is presented in Section D.3.4.4. The risks in the tables are displayed in the standard scientific (exponential) notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.3-3 presents an overview, by alternative, of the *total*, programwide risks of cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer incidence and construction and operational fatalities for waste management workers. These tables provide the estimated *total number* of people in the three receptor populations who will develop cancers from exposure to HW over a lifetime if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities.
- Table D.3.3-4 shows the sizes of the total affected populations for each alternative.
- Table D.3.3-5 summarizes the risks to the offsite and noninvolved worker MEIs for each HW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will develop cancer from chemical exposure or are indicators that the MEIs will suffer adverse health effects from exposure to noncarcinogenic, hazardous constituents.
- Tables D.3.3-6 through D.3.3-8 show the programwide risks for all receptors and health effect endpoints, by alternative.
- Tables D.3.3-9 through D.3.3-11 present offsite and worker population risks for each installation, by alternative.
- Table D.3.3-12 lists the hazardous constituents that contribute most of the risk of cancer incidence to the offsite population, by installation and alternative.

***Table D.3.3-3 Summary of Programwide Risks Associated With Routine Management of HW: Risks to Total Populations, by Alternative***

| | Offsite Population | WM Workers | | Noninvolved Worker Population |
|---|---|---|---|---|
| **Alternative** | **Chem CI** | **Chem CI** | **C&OF** | **Chem CI** |
| No Action | 7.5E-03 | 9.4E-02 | 8.2E-03 | 2.5E-03 |
| Regionalized 1 | 6.0E-02 | 1.2 | 6.9E-02 | 2.5E-02 |
| Regionalized 2 | 9.6E-02 | 1.8 | 7.3E-02 | 3.3E-02 |

Notes: Chem CI = cancer incidence associated with exposure to hazardous chemicals; C&OF = fatalities due to physical hazards during construction and operation of waste treatment facilities.

***Table D.3.3–4 Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by the Risks From Routine Management of HW, by Alternative***

| Alternative | Offsite Population | WM Workers | Noninvolved Worker Population |
|---|---|---|---|
| No Action | 1,034,713 | 52 | 12,260 |
| Regionalized 1 | 2,192,128 | 355 | 48,482 |
| Regionalized 2 | 1,034,713 | 372 | 12,260 |

***Table D.3.3–5 Summary of Programwide Risks Associated With Managing HW to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative***

| Alternative | Offsite MEI | | Noninvolved Worker MEI | |
|---|---|---|---|---|
| | Chem CI | HI | Chem CI | HI |
| No Action | 3.9E–07 | 2.6E–03 | 2.4E–06 | 1.6E–02 |
| Regionalized 1 | 2.4E–06 | 3.2E–02 | 1.1E–05 | 5.1E–01 |
| Regionalized 2 | 5.0E–06 | 6.6E–02 | 3.1E–05 | 4.1E–01 |

Notes: MEI = maximally exposed individual; Chem CI = cancer incidence associated with exposure to hazardous chemical.
HI = hazard index.

***Table D.3.3-6 Programwide Risks Associated With the Routine Management of HW Under the No Action Alternative, by Health Endpoint***

| Receptor | Endpoint | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|
| | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 2.5E-03 | | |
| | Genetic effects | | | |
| Noninvolved worker MEI | Dose (rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 2.4E-06 | | |
| | Genetic effects | | | |
| | Hazard index | | 1.6E-02 | |
| Offsite population | Dose (person-rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 7.5E-03 | | |
| | Genetic effects | | | |
| Offsite MEI | Dose (rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 3.9E-07 | | |
| | Genetic effects | | | |
| | Hazard index | | 2.6E-03 | |
| WM workers | Dose (FTE-rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 9.4E-02 | | |
| | Genetic effects | | | |
| | Exposure index | | 4.3 | |
| | Construction fatalities | | | 1.9E-03 |
| | Construction injuries | | | 8.4E-01 |
| | Operation fatalities | | | 6.3E-03 |
| | Operation injuries | | | 5.3 |

***Table D.3.3–7. Programwide Risks Associated With the Routine Management of HW Under Regionalized Alternative 1, by Health Endpoint***

| Receptor | Endpoint | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|
| | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 2.5E–02 | | |
| | Genetic effects | | | |
| Noninvolved worker MEI | Dose (rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 1.1E–05 | | |
| | Genetic effects | | | |
| | Hazard index | | 1.5E–01 | |
| Offsite population | Dose (person-rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 6.0E–02 | | |
| | Genetic effects | | | |
| Offsite MEI | Dose (rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 2.4E–06 | | |
| | Genetic effects | | | |
| | Hazard index | | 3.2E–02 | |
| WM workers | Dose (FTE-rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 1.2 | | |
| | Genetic effects | | | |
| | Exposure index | | 6.1 | |
| | Construction fatalities | | | 2.6E–02 |
| | Construction injuries | | | 1.2E+01 |
| | Operation fatalities | | | 4.3E–02 |
| | Operation injuries | | | 3.7E+01 |

***Table D.3.3–8. Programwide Risks Associated With the Routine Management of HW Under Regionalized Alternative 2, by Health Endpoint***

| Receptor | Endpoint | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|
| | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 3.3E–02 | | |
| | Genetic effects | | | |
| Noninvolved worker MEI | Dose (rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 3.1E–05 | | |
| | Genetic effects | | | |
| | Hazard index | | 4.1E–01 | |
| Offsite population | Dose (person-rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 9.6E–02 | | |
| | Genetic effects | | | |
| Offsite MEI | Dose (rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 5.0E–06 | | |
| | Genetic effects | | | |
| | Hazard index | | 6.6E–02 | |
| WM workers | Dose (FTE-rem) | | | |
| | Cancer fatalities | | | |
| | Cancer incidence | 1.8 | | |
| | Genetic effects | | | |
| | Exposure index | | 6.2 | |
| | Construction fatalities | | | 2.8E–02 |
| | Construction injuries | | | 1.2E+01 |
| | Operation fatalities | | | 4.5E–02 |
| | Operation injuries | | | 3.8E+01 |

***Table D.3.3–9. Risks Associated With the Routine Management of HW Under the No Action Alternative, by Site***

| Site | Population[a] | Fatalities[b] | Cancer Incidence | | | | |
|---|---|---|---|---|---|---|---|
| | | Workers | Offsite Population | Offsite MEI | Noninvolved Worker Population | Noninvolved Worker MEI | Workers |
| INEL | 153,061 / 16 | 2.6E–03 | 3.4E–05 | 4.6E–09 | 4.4E–05 | 3.7E–08 | 1.8E–02 |
| ORR | 881,652 / 36 | 5.6E–03 | 7.4E–03 | 3.9E–07 | 2.5E–03 | 2.4E–06 | 7.6E–02 |
| Total | | 8.2E–03 | 7.5E–03 | 3.9E–07 | 2.5E–03 | 2.4E–06 | 9.4E–02 |

Note: MEI = maximally exposed individual.
[a] Top number represents the offsite population within an 80-km (50-mi) radius of the site, while the bottom number represents the total FTEs for waste management workers involved in both construction and operation activities.
[b] Risk of cancer fatality from exposure to hazardous chemicals cannot be assessed; worker fatality risks reflect risks from physical hazards only.

***Table D.3.3–10. Risks Associated With the Routine Management of HW Under Regionalized Alternative 1, by Site***

| Site | Population[a] | Fatalities[b] | Cancer Incidence | | | | |
|---|---|---|---|---|---|---|---|
| | | Workers | Offsite Population | Offsite MEI | Noninvolved Worker Population | Noninvolved Worker MEI | Workers |
| Hanford | 377,645 / 91 | 1.8E–02 | 4.3E–03 | 1.4E–07 | 2.6E–03 | 5.0E–06 | 2.9E–01 |
| INEL | 153,061 / 35 | 6.8E–03 | 1.0E–04 | 1.4E–08 | 1.4E–04 | 1.1E–07 | 7.6E–02 |
| LANL | 159,152 / 88 | 1.7E–02 | 1.9E–02 | 2.4E–06 | 9.5E–03 | 5.9E–06 | 3.0E–01 |
| ORR | 881,652 / 101 | 2.0E–02 | 3.6E–02 | 1.8E–06 | 1.1E–02 | 1.1E–05 | 4.2E–01 |
| SRS | 620,618 / 40 | 7.9E–03 | 1.2E–03 | 1.5E–08 | 5.9E–04 | 6.7E–07 | 9.3E–02 |
| Total | | 6.9E–02 | 6.0E–02 | 2.4E–06 | 2.5E–02 | 1.1E–05 | 1.2 |

Note: MEI = maximally exposed individual.
[a] Top number represents the offsite population within an 80-km (50-mi) radius of the site, while the bottom number represents the total FTEs for waste management workers involved in both construction and operation activities.
[b] Risk of cancer fatality from exposure to hazardous chemicals cannot be assessed; worker fatality risks reflect risks from physical hazards only.

***Table D.3.3–11. Risks Associated With the Routine Management of HW Under Regionalized Alternative 2, by Site***

| Site | Population[a] | Fatalities[b] | Cancer Incidence | | | | |
|---|---|---|---|---|---|---|---|
| | | Workers | Offsite Population | Offsite MEI | Noninvolved Worker Population | Noninvolved Worker MEI | Workers |
| INEL | 153,061 / 160 | 3.1E–02 | 9.7E–04 | 1.3E–07 | 1.3E–03 | 1.1E–06 | 7.4E–01 |
| ORR | 881,652 / 212 | 4.1E–02 | 9.5E–02 | 5.0E–06 | 3.2E–02 | 3.1E–05 | 1.1 |
| Total | | 7.3E–02 | 9.6E–02 | 5.0E–06 | 3.3E–02 | 3.1E–05 | 1.8 |

Note: MEI = maximally exposed individual.
[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for waste management workers involved in both construction and operation activities.
[b] Risk of cancer fatality from exposure to hazardous chemicals cannot be assessed; worker fatality risks reflect risks from physical hazards only.

***Table D.3.3–12. Constituents in HW Contributing the Highest Risk of Cancer Incidence to the Offsite Population at Each Site, by Alternative***

| Alternative | Installation | | | | |
|---|---|---|---|---|---|
| | Hanford | INEL | LANL | ORR | SRS |
| No Action | — | Chromium (VI)[a] 2.7E–05[b] | — | Chromium (VI) 5.9E–03 | — |
| Regionalized 1 | Chromium (VI) 3.5E–03 | Chromium (VI) 8.3E–05 | Chromium (VI) 1.5E–02 | Chromium (VI) 2.9E–02 | Chromium (VI) 9.4E–04 |
| Regionalized 2 | — | Chromium (VI) 7.8E–04 | — | Chromium (VI) 7.7E–02 | — |

[a] Chromium in the source term was assumed to be 100% chromium (VI).
[b] Risk of cancer incidence contributed by this constituent.

### D.3.3.4 Results of the HW Human Health Risk Analysis for Routine Operations

The following sections present a summary of the estimated programwide impacts to each receptor population and a discussion of the overall results of the HW human health risk analysis.

#### D.3.3.4.1 *Programwide Trends in Human Health Risks Associated With HW Management Alternatives*

**Offsite Population**. For the offsite population, the programwide risk of cancer incidence associated with routine treatment of HW is lowest for No Action (7.5E–03 cancer incidences distributed over a total affected population of approximately 1 million), and slightly higher for Regionalized 1 and 2 (6.0E–02 over a total population of approximately 2 million and 9.6E–02 over approximately 1 million, respectively). As would be expected based on the waste consolidation and treatment scenarios, cancer incidence risks at INEL and ORR are slightly higher in Regionalized 2 than Regionalized 1 (recall that in Regionalized 2,80% to 90% of the DOE inventory of commercially treatable HW is consolidated and treated at these two sites).

**Noninvolved Worker Population**. The programwide risk of cancer incidence to the noninvolved worker population follows the same pattern as for the offsite population: Regionalized 1 and 2 risks are similar to one another (both are in the E–02 order of magnitude) and approximately 1 order of magnitude higher than in No Action. However, the total affected noninvolved worker populations (approximately 12,260 in No Action and Regionalized 2 and 48,482 in Regionalized 1) are substantially smaller than the total offsite populations. Therefore, the relative risks "per capita" (the risks to an average member of the noninvolved worker population compared to an average member of the offsite population) are concomitantly higher. This higher individual risk to members of the noninvolved worker population is also reflected in the results for the offsite and noninvolved worker MEIs.

**Maximally Exposed Noninvolved Worker and Offsite Individual**. For the offsite and noninvolved worker MEIs, risk of cancer incidence follows the same pattern as for their respective populations. However, the risks of cancer incidence for both of these receptors in Regionalized 1 and 2 are in the E–05 to E–06 range.

Most of the MEI risk in these alternatives is attributable to the presence of the inhalation carcinogen chromium (VI) in the source term (ANL, 1996d). The hazard indices for both MEIs (indicating the greatest individual exposure to noncarcinogenic chemicals per scenario) follow the trend for cancer incidence but are less than 1.0 in all alternatives. This indicates a low probability that these receptors will suffer adverse effects from exposure to noncarcinogenic, toxic contaminants.

**Workers**. Programwide health risks to workers follow the same general trends as for the offsite and noninvolved worker populations. The total risks of cancer incidence in Regionalized 1 and 2 are slightly more than 1 order of magnitude higher than in No Action, and range from 1.8E–02 to 1.1. While the air concentrations of each HW constituent component are estimated to be at or below TLVs, the sum of the exposures from those concentrations yields exposure indices that are consistently above 1.0 (ranging from 4.1 to 8.2) in all alternatives. This indicates that the worker receiving the worst-case exposure is potentially at risk of adverse health effects from the daily inhalation of fugitive chemical emissions in all three alternatives. These results indicate that the risk of cancer incidence to the total worker population increases as a greater percentage of the DOE HW inventory is treated and as treatment is performed at fewer consolidation sites, while the highest individual exposure to hazardous, noncarcinogenic chemicals differs little from alternative to alternative.

As can be seen in Tables D.3.3–9 through D.3.3–11, the highest risks of cancer incidence to workers result at INEL and ORR under Regionalized 2, in which these two sites treat 80% to 90% of the DOE inventory of commercially treatable HW. The difference in risks at these sites between Regionalized 1 and 2 is about 0.5 to 1 order of magnitude.

Construction and operational injuries and fatalities follow the same pattern as exposure risks to workers and other populations (see Tables D.3.3–6 through D.3.3–8). No Action involves the least construction, the smallest volume of waste in treatment, and the fewest workers. Accordingly, the No Action risks from physical hazards are the lowest among the three alternatives. The risks from physical hazards in Regionalized 1 and 2 are almost identical to one another and reflect increased person-hours spent building and operating waste processing facilities compared to No Action.

#### D.3.3.4.2 *Summary of Results for Routine Treatment of HW*

For the offsite population, ORR poses the highest risk of cancer incidence in No Action and Regionalized 2; ORR and LANL pose the highest risks in Regionalized 1 (see Tables D.3.3–9 through D.3.3–11). INEL presents the lowest cancer incidence risks in all alternatives. Inhaled chromium (VI) contributes the most risk of cancer incidence to the offsite population at all sites across all alternatives (see Table D.3.3–12). Cancer incidence risks to the offsite MEI are in the E–06 order of magnitude at LANL in Regionalized 1 and ORR in Regionalized 1 and 2.

Risks to the various noninvolved worker populations tend to parallel the risks to the site-specific offsite populations. ORR presents the highest risk of cancer incidence in No Action and Regionalized 2; and ORR, LANL, and Hanford pose the highest risks in Regionalized 1. Inhalation of chromium (VI) contributes most of the cancer incidence risk at all sites in all alternatives (ORNL, 1996).

The cancer incidence risk to the noninvolved worker MEI is between 1.0E–06 and 1.0E–04 at ORR in No Action; ORR, LANL, and Hanford in Regionalized 1; and ORR and INEL in Regionalized 2. Hazard indices for both MEIs are below 1.0 in all alternatives, indicating a low probability of adverse effects from exposure to noncarcinogenic, toxic contaminants.

The highest site cancer incidence risks are always at ORR for workers, although differences between sites in cancer incidence for workers are consistently less than 1 order of magnitude. The controlling contaminants at ORR for worker cancer incidence are chromium (VI) in No Action and vinyl chloride and chromium (VI) in Regionalized 1 and 2. In No Action, the exposure index at ORR is slightly higher than at INEL; the controlling contaminants at ORR are chlorine and cadmium. In Regionalized 1 and 2, exposure indices at all sites are approximately equal; controlling contaminants are hydrogen chloride, chlorine, cadmium, copper, lead, and nickel.

#### D.3.3.4.3 *Discussion*

As noted in the summary of HW alternatives (Section D.3.3.1), No Action involves only the incineration of the INEL and ORR inventories of HW, while Regionalized 1 and 2 involve treatment of consolidated HW waste loads (50% and 80 to 90%, respectively) by incineration and waste fuel burning. Accordingly,

risks to the various receptors would be expected to increase as the amount of waste treated at DOE sites and the degree of consolidation increase. While the differences among alternatives are relatively small, this trend is apparent. Health risks associated with Regionalized 1 and 2 are slightly higher than those associated with No Action by about 1 order of magnitude. The risks for Regionalized 1 and 2 are approximately the same for all populations and health effects endpoints. In other words, treating 50% of the DOE inventory of HW at five sites and treating 80% to 90% at two sites results in nearly the same overall health risks to all populations. Within each alternative, the highest-risk sites for exposure are also the highest-risk sites for construction and operational risks. This indicates that the volume of waste being treated and, consequently, the number of hours workers spend constructing facilities and processing the waste, are the determining factors for health risks.

Comparison of the risks to the overall populations and MEIs in Regionalized 1 and 2 (see Tables D.3.3–10 and D.3.3–11) shows that risks generally differ by less than a factor of 2 between the two alternatives (which is reasonable since the difference in the amount of waste processed does not quite double between the alternatives). However, the risks in Regionalized 1 are distributed over twice as many members of the offsite population and four times as many members of the noninvolved worker population as in Regionalized 2.

### D.3.3.5 Summary of Alternatives for Potential HW Accidents

Three categories of potential HW accidents were analyzed for Regionalized 1 and 2: single-drum, single-contaminant accidents occurring during storage; multiple-contaminant storage facility accidents; and multiple-contaminant treatment facility accidents.

#### D.3.3.5.1 *Single-Drum Accidents*

Thirty-one storage accidents involving the release of a single chemical (either a carcinogen or a hazardous noncarcinogen) from a single drum were postulated for each site and each alternative. These single-drum accident scenarios are summarized in Table D.3.3–13.

There were three general types of single-drum accidents: a spill; a spill plus fire; and other combinations of events (spill plus explosion, fire only, fire plus explosion, etc.). Because of the large number of accidents to be analyzed, only the results of the four accidents for which the attendant risks are highest at each site for each alternative are reported in Table D.3.3–15, which can be found in Section D.3.3.7. These results are:

- The estimated cancer incidence in the site's offsite population for an accident involving a carcinogen.
- The hazard index for the offsite MEI for an accident involving a hazardous noncarcinogen.
- The estimated cancer incidence for the shift of six FTEs (hypothetical workers) working during an accident involving a carcinogen.
- The IDLH index (see Section D.2.11) for the maximally exposed FTE working during an accident involving a hazardous noncarcinogen.

The consequences of a single-drum accident release (if the accident occurred) do not differ among alternatives. However, the estimated annual frequency of the accident may differ among alternatives (i.e., an accident may become more likely as more drums are stored at a site).

Note that the single-drum accident that poses the highest risks to the offsite population may not be the same as the maximum reasonably foreseeable accident for workers (because exposure scenarios and pathways often differ between workers and the other receptors).

#### D.3.3.5.2 *Storage Facility Accidents*

Potential storage facility HW accidents include (1) a facility fire that engulfs a significant fraction of the containers in storage, releasing some or all of these contaminants: 2A, 2B, 2C, 2D, 5E, and 5F (see Table D.3.3–13); (2) an earthquake that ruptures a significant number of drums, releasing some or all of these contaminants: 1A, 1B, 1C, 1D, 4E, 4F, and 4G in Table D.3.3–13; and (3) the crash of a large aircraft (at Hanford, INEL, and SRS) or small aircraft (at LANL and ORR) resulting in a fire that burns a significant portion of the storage drums releasing some or all of these contaminants: 2A, 2B, 2C, 2D, 3A, 3D, 5E, and 5F in Table D.3.3–13. Earthquake-related storage accidents were postulated for Hanford and LANL only in Regionalized 1 and for INEL and ORR in Regionalized 2.

***Table D.3.3–13. Summary of Single-Drum Accident Scenarios for HW***

| Scenario | Accident Category | Toxic Gases Released |
|---|---|---|
| Spill | 1A | Ammonia |
| | 1B | Hydrogen chloride |
| | 1C | Hydrogen fluoride |
| | 1D | Sulfur oxides |
| Spill and fire | 2A | Polyaromatic hydrocarbon soot, unburnt hydrocarbons and carbon monoxide |
| | 2B | Hydrogen fluoride |
| | 2C | Cyanide |
| | 2D | Mercury vapor |
| Spill, fire, and gas cylinder explosion | 3A | Ammonia |
| Fire and gas cylinder breach | 3B | Ammonia |
| Fire and gas cylinder breach | 3C | Ammonia |
| Spill and explosion | 3D | Ammonia |
| Fire and explosion | 3E | Ammonia |
| Spill | 4A | Ammonia |
| | 4B | Hydrogen chloride |
| | 4C | Hydrogen fluoride |
| | 4D | Sulfur oxides |
| | 4E | Acetic acid |
| | 4F | Carbon disulfide |
| | 4G | 1,1,1-Trichloroethane |
| Fire | 5A | Polyaromatic hydrocarbon soot and unburnt hydrocarbons |
| | 5B | Hydrogen fluoride |
| | 5C | Cyanide |
| | 5D | Mercury vapor |
| | 5E | Cadmium fumes |
| | 5F | Dust from burnt and unburnt potassium and sodium dichromate salts |
| Spill, fire, and gas cylinder explosion | 6A | Ammonia |
| Fire and gas cylinder breach | 6B | Ammonia |
| Fire and gas cylinder breach | 6C | Ammonia |
| Spill and explosion | 6D | Ammonia |
| Fire and gas cylinder explosion | 6E | Ammonia |

#### D.3.3.5.3 *Treatment Facility Accidents*

The treatment facility accidents analyzed for HW include (1) an incinerator explosion and resulting fire; (2) an earthquake with subsequent fire; and (3) a large or small aircraft impact (assuming the same scenarios as for the storage facility accidents) and resulting fire. All three types of incinerator accidents involve a fire and a release of some or all of these contaminants: 2A, 2B, 2C, 2D, 5E, and 5F.

### D.3.3.6 Special Assumptions and Considerations Used in the HW Accident Analysis

The source terms for the HW accidents include the period of time over which a particular accident release occurs. For assessing risks to offsite and noninvolved worker receptors from single-drum and facilitywide accidents, all releases have been averaged for a 1-h release (i.e., for contaminant releases greater than 60 min in duration, the amount released was scaled to reflect a 60-min release; for contaminant releases of less than 60 min in duration, the total amount of contaminant is assumed to be released in 60 min).

In estimating the risks to the offsite and noninvolved worker populations, releases from storage facility accidents are assumed to be ground releases without flow (i.e., releases at ground level); releases from incinerator facility accidents are assumed to be stack releases with flow (i.e., release from the stack of an operating facility).

All storage accidents are assumed to involve six workers, the average number of workers needed to place waste in storage facilities (EG&G, 1992). For treatment (incineration) accidents, one shift of workers is assumed to be present in the facility when the accident occurs; shift size varies with the waste processing rate. For HW, from one to five workers are present during treatment accidents (see Table D.3.3–20 in Section D.3.3.7) (EG&G, 1992).

All releases from storage accidents are assumed to take place outside at an outdoor storage facility. A 5-min worker exposure duration is assumed for outdoor exposures to accidents that are readily visually detectable (fires, explosions, spills plus fire, etc.). For spills alone (which may not be noticed as quickly), a 10-min exposure period is assumed. Outdoor worker exposure concentrations were calculated using the INEXPLC

model for close-in atmospheric dispersion, explosive releases, and particle deposition (ORNL, 1993), using the following assumptions:

- The worker is standing directly downwind of the release.
- The release height is 0 m (i.e., at ground level).
- The receptor height is 1.5 m (i.e., the height of the person's nose).
- The radius of the source is 1.5 m.
- Receptor distances were varied from 1 m to 25 m at 1-m intervals and concentrations calculated at each interval; an average of these concentrations was used as the exposure concentration.
- Simple gas dispersion with no particle settling takes place.

Incineration accidents are accompanied by releases into an indoor operating gallery where the workers are located. Half the gallery (e.g., an area 32 m long × 6 m wide × 6 m high) is assumed to fill with contaminated air. An exposure duration of 1 min is assumed, during which workers avoid any obstructions and leave the scene. Indoor worker exposure concentrations are estimated using a room model with no ventilation.

Cancer potency factors from the EPA Integrated Risk Information System and Health Effects Assessment Summary Tables were used for determining the cancer incidence resulting from accidents that released carcinogenic chemicals. RfCs and lethality concentrations for acute exposure to toxic chemicals are derived from the methodology developed by Hartmann et al. (1994). Cadmium and benzene are considered to be the carcinogens in the HW accident source terms. Cadmium is toxic as well as carcinogenic, so it is incorporated into both the IDLH index and cancer incidence risk for workers. For the offsite and noninvolved worker populations exposed to cadmium, only the risk of cancer incidence is evaluated because no acute RfD is available to calculate a hazard index. The toxicity and slope factors and IDLH values for cadmium dust are used for accident subcategory 5E because no analogous values are available for cadmium fumes.

The chemical surrogates in Table D.3.3–14 are used in the HW accident risk estimates for all receptors. Hazardous waste manifests for the transport of HW were often not explicit as to exact chemical components, giving only general categories. As a result, a more toxic chemical in a general category was chosen as a conservative representative of the entire category.

*Table D.3.3-14. Chemical Surrogates Used in Risk Analysis for Potential HW Accidents*

| Chemical Hypothetically Released in Accident | Surrogate Used in Risk Analysis |
|---|---|
| Cyanides (hydrogen, potassium, etc.) | Hydrogen cyanide |
| Dichromate salts (potassium, sodium, etc.) | Potassium dichromate |
| Polyaromatic hydrocarbon soot and unburnt hydrocarbons | Benzene |
| Sulfur oxides | Sulfur dioxide |

There is an associated estimated annual frequency of occurrence for each accident type (see Section D.2.12.1). However, the probability of occurrence is not taken into account in the risk calculations. Risk estimates associated with each accident should be interpreted as the consequences if the accident occurred. The various single drum accidents have estimated annual frequencies of occurrence ranging from "unlikely" (1.0E-04 to 1.0E-02) to "very unlikely"(1.0E-06 to 1.0E-04). The incinerator explosion and fire is considered to be "anticipated" (greater than 1.0E-02); the earthquake causing a storage facility spill or an incinerator fire is considered "unlikely" to "very unlikely," depending on the location of the site; and aircraft impact is regarded as "extremely unlikely" (less than 1.0E-06), depending on site location (see Appendix F).

### D.3.3.7 Results Tables for the Risk Analysis of Potential HW Accidents

Table D.3.3-15 shows a summary of the risks to the offsite and waste management worker populations from the most conservative single-drum, single-contaminant releases, by site and alternative. Tables D.3.3-16 through D.3.3-19 present a summary of risks to the offsite, noninvolved worker, and waste management worker populations for treatment and storage facility accidents, by site and alternative. Table D.3.3-20 provides the sizes of the offsite, noninvolved worker, and worker populations at each site.

***Table D.3.3–15. Summary of Risks to the Offsite and Waste Management Worker Populations From Potential Single-Drum HW Accidents, by Alternative and Site***

| | | Receptor and Endpoint | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Offsite Population | | Offsite MEI | | Worker Population | | Maximally Exposed Worker | |
| Site | Alternative | Accident[a] | CI | Accident | HI | Accident | CI | Accident | IDLH Index |
| Hanford | Reg. 1 | 5E (U)[b] | 3.2E–04 | 2D (U) | 8.1E–02 | 5E (U) | 2.5E–03 | 5F (VU) | 6.4E+01 |
| INEL | Reg. 1 | 5E (U) | 2.1E–04 | 2D (U) | 5.3E–01 | 5E (U) | 2.5E–03 | 5F (U) | 6.4E+01 |
| LANL | Reg. 1 | 5E (U) | 3.0E–04 | 2D (U) | 9.9E–01 | 5E (U) | 2.5E–03 | 5F (U) | 6.4E+01 |
| ORR | Reg. 1 | 5E (VU) | 5.9E–03 | 2D (U) | 5.8 | 5E (VU) | 2.5E–03 | 5F (VU) | 6.4E+01 |
| SRS | Reg. 1 | 5E (U) | 2.6E–05 | 2D (U) | 8.1E–02 | 5E (U) | 2.5E–03 | 5F (0)[c] | 6.4E+01 |
| INEL | Reg. 2 | 5E (U) | 2.1E–04 | 2D (U) | 5.3E–01 | 5E (U) | 2.5E–03 | 5F (U) | 6.4E+01 |
| ORR | Reg. 2 | 5E (U) | 5.9E–03 | 2D (U) | 5.8 | 5E (U) | 2.5E–03 | 5F (U) | 6.4E+01 |

Notes: MEI = maximally exposed individual; CI = risk of cancer incidence associated with exposure to chemical carcinogens; HI = hazard index associated with exposure to noncarcinogenic, hazardous chemicals; Reg.1 = Regionalized Alternative 1; Reg. 2 = Regionalized Alternative 2.

[a] Maximum reasonably foreseeable single-drum accident type.

[b] Accident annual frequency codes are "A" for anticipated (>1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (<1.0E–06).

[c] The annual frequency of this accident occurring at SRS is 0.

***Table D.3.3–16. Risks Associated With Potential Facilitywide HW Storage Accidents Under Regionalized Alternative 1, by Accident and Site***

| Site | Offsite Pop CI | Offsite MEI HI | Noninvolved Worker Pop CI | Noninvolved Worker MEI HI | Worker CI | Worker IDLH Index |
|---|---|---|---|---|---|---|
| **Storage Facility Fire** | | | | | | |
| Hanford (U)[a] | 2.8E–03 | 1.1 | 1.5E–05 | 5.6 | 1.8E–02 | 9.0E+02 |
| INEL (U) | 1.7E–03 | 1.5 | 6.8E–03 | 1.4E+01 | 2.0E–02 | 5.1E+02 |
| LANL (U) | 8.3E–03 | 3.1E+01 | 1.8E–03 | 4.4E+02 | 6.6E–02 | 2.4E+03 |
| ORR (U) | 1.8E–02 | 7.6E+01 | 2.3E–02 | 8.4E+02 | 5.3E–03 | 6.0E+02 |
| SRS (U) | 5.6E–04 | 1.7 | 2.8E–03 | 1.1E+02 | 5.4E–02 | 1.3E+03 |
| **Large or Small Aircraft Impact and Storage Facility Fire** | | | | | | |
| Hanford (EU) (large) | 2.8E–03 | 1.2 | 1.4E–05 | 6.2 | 1.8E–02 | 1.4E+03 |
| INEL (EU) (large) | 1.7E–03 | 1.6 | 6.9E–03 | 1.4E+01 | 2.0E–02 | 5.3E+02 |
| LANL (EU) (small) | 8.3E–03 | 3.2E+01 | 1.8E–03 | 4.5E+02 | 6.6E–02 | 2.7E+03 |
| ORR (EU) (small) | 1.8E–02 | 7.7E+01 | 2.3E–02 | 8.5E+02 | 5.3E–03 | 6.8E+02 |
| SRS (EU) (large) | 5.9E–04 | 1.7 | 2.8E–03 | 1.1E+02 | 5.4E–02 | 1.3E+03 |
| **Earthquake and Resulting Spill of Multiple Storage Containers** | | | | | | |
| Hanford (VU) | 0.0[b] | 1.6E–03 | 0.0[b] | 8.5E–03 | 0.0[b] | 1.2 |
| LANL (U) | 0.0[b] | 2.0E–02 | 0.0[b] | 2.8E–01 | 0.0[b] | 1.2 |

Notes: CI = risk of cancer incidence associated with exposure to chemical carcinogens; MEI = maximally exposed individual; HI = hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[a] Accident annual frequency codes are "A" for anticipated (>1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (<1.0E–06).
[b] Zero indicates that no carcinogen is released in accident scenario.

***Table D.3.3–17. Risks Associated With Potential Facilitywide HW Storage Accidents Under Regionalized Alternative 2, by Accident and Site***

| Site | Offsite Pop CI | Offsite MEI HI | Noninvolved Worker Pop CI | Noninvolved Worker MEI HI | Worker CI | Worker IDLH Index |
|---|---|---|---|---|---|---|
| **Storage Facility Fire** | | | | | | |
| INEL (U)[a] | 1.2E–02 | 3.6E+01 | 4.8E–02 | 3.2E+02 | 1.4E–01 | 5.1E+03 |
| ORR (U) | 1.6E–01 | 2.4E+02 | 2.1E–01 | 2.6E+03 | 6.1E–02 | 2.2E+03 |
| **Large or Small Aircraft Impact With Resulting Fire** | | | | | | |
| INEL (EU) (large) | 1.2E–02 | 3.7E+01 | 4.8E–02 | 3.3E+02 | 1.4E–01 | 6.2E+03 |
| ORR (EU) (small) | 1.6E–01 | 2.4E+02 | 2.1E–01 | 2.6E+03 | 6.1E–02 | 2.3E+03 |
| **Earthquake and Resulting Spill of Multiple Storage Containers** | | | | | | |
| INEL (U) | 0.0[b] | 1.9E–01 | 0.0[b] | 1.7 | 0.0[b] | 8.0 |
| ORR (U) | 0.0[b] | 1.1E–01 | 0.0[b] | 1.3 | 0.0[b] | 1.2 |

Notes: CI = risk of cancer incidence associated with exposure to chemical carcinogens; MEI = maximally exposed individual; HI = hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[a] Accident annual frequency codes are "A" for anticipated (>1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (<1.0E–06).
[b] Zero indicates that no carcinogen is released in accident scenario.

***Table D.3.3–18. Risks Associated With Potential Facilitywide HW Treatment Accidents Under Regionalized Alternative 1, by Accident and Site***

| Site | | Offsite Pop CI | Offsite MEI HI | Noninvolved Worker Pop CI | Noninvolved Worker MEI HI | Worker CI | Worker IDLH Index |
|---|---|---|---|---|---|---|---|
| **Incinerator Explosion and Fire** | | | | | | | |
| Hanford | (A)[a] | 1.9E–05 | 8.0E–02 | 9.8E–08 | 4.3E–01 | 1.0E–06 | 3.9E+01 |
| INEL | (A) | 2.0E–04 | 0.0[b] | 4.7E–04 | 0.0[b] | 2.5E–04 | 7.9E+01 |
| LANL | (A) | 3.1E–04 | 9.5E–01 | 6.1E–05 | 7.3 | 7.5E–04 | 1.2E+02 |
| ORR | (A) | 5.5E–03 | 3.5 | 4.8E–04 | 3.7 | 1.0E–03 | 2.0E+02 |
| SRS | (A) | 7.6E–07 | 8.0E–02 | 3.4E–06 | 4.4 | 5.0E–07 | 3.9E+01 |
| **Large or Small Aircraft Impact With Resulting Fire** | | | | | | | |
| Hanford (large) | (EU) | 5.6E–05 | 1.8E–01 | 2.9E–07 | 9.8E–01 | 3.0E–06 | 3.6E+02 |
| INEL (large) | (EU) | 4.1E–04 | 8.3E–02 | 9.4E–04 | 4.6E–01 | 5.0E–04 | 2.3E+02 |
| LANL (small) | (EU) | 3.4E–04 | 1.3 | 6.6E–05 | 9.9 | 7.6E–04 | 4.8E+02 |
| ORR (small) | (EU) | 1.1E–02 | 6.8 | 9.7E–04 | 7.1 | 2.0E–03 | 3.2E+02 |
| SRS (large) | (EU) | 2.9E–05 | 8.1E–02 | 1.3E–04 | 4.4 | 5.0E–04 | 1.2E+02 |
| **Earthquake With Resulting Fire** | | | | | | | |
| Hanford | (VU) | 3.7E–05 | 1.0E–01 | 2.0E–07 | 5.5E–01 | 2.0E–06 | 3.2E+02 |
| INEL | (VU) | 2.1E–04 | 8.3E–02 | 4.8E–04 | 4.6E–01 | 2.5E–04 | 1.6E+02 |
| LANL | (VU) | 3.5E–04 | 1.0 | 6.8E–05 | 7.8 | 7.8E–04 | 2.0E+02 |
| ORR | (VU) | 1.1E–02 | 6.8 | 9.7E–04 | 7.1 | 2.0E–03 | 3.2E+02 |
| SRS | (VU) | 2.7E–05 | 8.1E–02 | 1.2E–04 | 4.4 | 5.0E–04 | 1.2E+02 |

Notes: CI = risk of cancer incidence associated with exposure to chemical carcinogens; MEI = maximally exposed individual; HI = hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[a] Accident annual frequency codes are "A" for anticipated (> 1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (< 1.0E–06).
[b] Zero indicates that no acute RfD was available for contaminant; cancer incidence only was calculated.

***Table D.3.3-19. Risks Associated With Potential Facilitywide HW Treatment Accidents Under Regionalized Alternative 2, by Accident and Site***

| Site | Offsite Pop CI | Offsite MEI HI | Noninvolved Worker Pop CI | Noninvolved Worker MEI HI | Worker CI | Worker IDLH Index |
|---|---|---|---|---|---|---|
| **Incinerator Explosion and Fire** | | | | | | |
| INEL (A)[a] | 2.3E-04 | 4.9E-01 | 5.2E-04 | 2.7 | 1.3E-03 | 2.0E+02 |
| ORR (A) | 6.0E-03 | 6.6 | 5.2E-04 | 6.9 | 1.3E-03 | 1.6E+02 |
| **Large or Small Aircraft Impact With Resulting Fire** | | | | | | |
| INEL (large) (EU) | 4.5E-04 | 1.5 | 1.0E-03 | 8.5 | 2.5E-03 | 6.4E+02 |
| ORR (small) (EU) | 1.2E-02 | 1.1E+01 | 1.0E-03 | 1.1E+01 | 2.5E-03 | 5.6E+02 |
| **Earthquake With Resulting Fire** | | | | | | |
| INEL (VU) | 8.6E-04 | 2.1 | 2.0E-03 | 1.2E+01 | 5.0E-03 | 9.9E+02 |
| ORR (VU) | 1.2E-02 | 1.1E+01 | 1.0E-03 | 1.1E+01 | 2.5E-03 | 5.6E+02 |

Notes: CI = risk of cancer incidence associated with exposure to chemical carcinogens; MEI = maximally exposed individual; HI = hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[a] Accident annual frequency codes are "A" for anticipated (> 1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (< 1.0E-06).

***Table D.3.3-20. Size of Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Potential HW Treatment and Storage Accidents, by Site***

| Site | Offsite Population | Noninvolved Worker Population | Storage Worker Population | | Treatment Worker Population | |
|---|---|---|---|---|---|---|
| | | | Regionalized 1 | Regionalized 2 | Regionalized 1 | Regionalized 2 |
| Hanford | 377,645 | 8,674 | 6 | | 2 | |
| INEL | 153,061 | 8,451 | 6 | 6 | 1 | 5 |
| LANL | 159,152 | 11,552 | 6 | | 3 | |
| ORR | 881,652 | 3,809 | 6 | 6 | 4 | 5 |
| SRS | 620,618 | 15,996 | 6 | | 2 | |

### D.3.3.8 Summary of the HW Accident Analysis Results

In general, the accident analyses indicate the same trend as seen in routine waste management operations: as the volume of waste is increased at a site, the risks to the public and workers during treatment and storage increase. In Regionalized Alternative 2, approximately 80% of DOE-generated HW is treated at two sites, while treatment of 50% of DOE HW is distributed across five sites in Regionalized 1. Accordingly, the accident risks to all receptors at INEL and ORR in Regionalized 2 tend to be higher than the Regionalized 1 risks at these sites by roughly 1 order of magnitude for storage accidents and by only a slight margin for treatment accidents.

The single-drum storage accidents with the greatest risks to the offsite population and MEI involve releases of cadmium and mercury vapor. The single-drum accidents with the greatest risks to workers involve releases of cadmium and dichromate salts. The facility-wide storage accidents that would produce the highest risks to all receptors are the storage facility fire and the crash of an aircraft into a storage facility followed by fire. However, the storage facility fire is considered "unlikely" (1.0E–04 to 1.0E–02), whereas the aircraft impact scenario is designated "extremely unlikely" (less than 1.0E–06). For treatment facility accidents, consequences are generally similar among accident types at a given site; however, the incinerator explosion is considered much more likely (greater than 1.0E–02 or "anticipated") than other scenarios. The most common controlling contaminants in HW accident scenarios are cadmium and mercury vapor. The highest-risk sites are usually INEL, ORR, and LANL.

#### D.3.3.8.1 *Risks to the Offsite Population From Accidents During Storage*

**Single-Drum Accidents.** For the offsite population at each site, the highest cancer incidence risks are associated with a forklift accident resulting in a spill and fire involving a release of cadmium fumes (5E) (see Table D.3.3–15). These risks of cancer incidence range from 2.6E–05 to 5.9E–03 in Regionalized 1 and from 2.1E–04 to 5.9E–03 in Regionalized 2. The highest cancer incidence is at ORR in both Regionalized 1 and 2 (5.9E–03 occurrences affecting a population of 881,652). The next highest risks of cancer incidence are at Hanford and LANL in Regionalized 1 and at INEL in both alternatives (3.2E–04, 3.0E–04, and 2.1E–04, respectively). The lowest cancer incidence risks are at SRS in Regionalized 1 (2.6E–05). The consequences at a site of the maximum reasonably foreseeable single-drum accident (if it occurred) do not differ between alternatives. However, the estimated annual frequency of the accident

increases almost 2 orders of magnitude at ORR from "very unlikely" (1.0E–06 to 1.0E–04) to "unlikely" (1.0E–04 to 1.0E–02) in Regionalized 2. The accident is considered "unlikely" at all other sites in both alternatives.

**Storage Facility Accidents**. For the offsite population, storage facility fires and aircraft impacts with subsequent fires would pose about the same risks of cancer incidence if they occurred at a site (see Tables D.3.3–16 and D.3.3–17). However, facility fires are projected to occur more frequently than airplane crashes ("unlikely" [1.0E–04 to 1.0E–02] versus "extremely unlikely" [less than 1.0E–06], respectively). In general, the risks at each site are 1 order of magnitude higher in Regionalized 2 than in Regionalized 1. This is because approximately 80% of DOE-generated HW is treated at two sites in Regionalized 2 while treatment of 50% of DOE HW is distributed across five sites in Regionalized 1.

The highest cancer incidence risks from a storage facility fire or an airplane impact affecting a storage facility are at ORR in Regionalized 1 and 2 (1.8E–02 and 1.6E–01, respectively, in an affected population of 881,652), INEL in Regionalized 2 (1.2E–02 in a population of 153,061), and LANL in Regionalized 1 (8.3E–03 in a population of 159,152) (ANL, 1996f). At all three sites, the controlling contaminant is cadmium.

### D.3.3.8.2 *Risks to the Offsite Population From Accidents During Treatment*

The risks of cancer incidence to the offsite population from facility-wide accidents during incineration range from 7.6E–07 to 1.1E–02 in Regionalized 1 and from 2.3E–04 to 1.2E–02 in Regionalized 2. In Regionalized 1, cancer incidence risks to the offsite population are similar among accident types (incinerator explosion, aircraft crash into a incinerator facility, and earthquake and fire affecting an incinerator facility) at a given site, differing by only a factor of three or less in most instances. One exception is the incinerator explosion scenario at SRS, which results in a cancer incidence to the offsite population (7.6E–07) that is more than 1 order of magnitude lower than other accident types at SRS. (This is because the carcinogen cadmium is released in the other accident types, but not in the incinerator explosion scenario.) Cancer incidence risks to the offsite population are also similar among accident types at INEL and ORR in Regionalized 2, differing by less than a factor of four. However, in both alternatives, the estimated annual

frequency associated with each of the three treatment facility accident scenarios is different: the incinerator explosion is considered "anticipated" (estimated annual frequency greater than 1E–02); the aircraft impact scenario is "extremely unlikely" (less than 1E–06); and the earthquake scenario is "very unlikely" (1E–06 to 1E–04).

ORR is the highest-risk site for all accident types and alternatives. The highest cancer incidence risks are for the aircraft impact or the earthquake at ORR in both alternatives (1.1E–02 in Regionalized 1 and 1.2E–02 in Regionalized 2). The driving contaminant at ORR for these accident types is cadmium.

#### D.3.3.8.3 *Risks to the Noninvolved Worker Population From Accidents During Storage*

The risk of cancer incidence in the noninvolved worker population due to accident-related releases follows a similar pattern to that for the offsite population. At each site, storage facility fires and aircraft impacts with subsequent fires pose about the same risks of cancer incidence (see Tables D.3.3–16 and D.3.3–17); however, facility fires are projected to occur more frequently than airplane crashes ("unlikely" versus "extremely unlikely," respectively). Accident risks in Regionalized 2 are approximately 1 order of magnitude higher than those in Regionalized 1 for each site. This is due to a greater number of breached containers involved in the Regionalized 2 accident scenarios. Cancer incidence due to storage accidents ranges from 1.4E–05 to 2.3E–02 in Regionalized 1 and from 4.8E–02 to 2.1E–01 in Regionalized 2.

For the airplane impact affecting a storage facility and the storage facility fire, the highest cancer incidence risks are at ORR in Regionalized 1 and 2 (2.3E–02 and 2.1E–01, respectively, in an affected population of 3,809). The next highest cancer incidence risks are from an airplane impact or storage facility fire at INEL (approximately 7.0E–03 in Regionalized 1 and 4.8E–02 in Regionalized 2). Cadmium is the controlling contaminant at both sites. The site with the lowest cancer incidence risks to noninvolved workers from storage accidents is Hanford in Regionalized 1.

#### D.3.3.8.4 *Risks to the Noninvolved Worker Population From Accidents During Treatment*

The risks of cancer incidence to the noninvolved worker population from facility-wide accidents during incineration range from 9.8E–08 to 9.7E–04 in Regionalized 1 and from 5.2E–04 to 2.0E–03 in

Regionalized 2. In both alternatives, cancer incidence risks to noninvolved workers are similar among accident types at a given site, differing by only a factor of three or less in most instances. One exception is the incinerator explosion scenario at SRS which results in a cancer incidence (3.4E–06) that is nearly 2 orders of magnitude lower than other accident types at SRS. (This is because the carcinogen cadmium is released in the other accident types, but not in the incinerator explosion scenario.)

The highest site risks of cancer incidence are at ORR and INEL for all accident types. Cancer incidence risks to noninvolved workers at INEL range from 4.7E–04 to 9.4E–04 in Regionalized 1 and from 5.2E–04 to 2.0E–03 in Regionalized 2. ORR cancer incidence risks are very similar to those at INEL, ranging from 4.8E–04 to 9.7E–04 in Regionalized 1 and from 5.2E–04 to 1.0E–03 in Regionalized 2. The controlling contaminant is cadmium at both sites.

### D.3.3.8.5 *Risks to the Maximally Exposed Offsite Individual From Single-Drum Accidents*

The maximum reasonably foreseeable single-drum accident involving the release of a noncarcinogenic chemical is a forklift accident that results in a spill and fire with release of mercury vapor (2D) (see Table D.3.3-15). The highest hazard index is at ORR in both alternatives (5.8), indicating an increased likelihood of adverse health effects. The next highest hazard index resulting from this accident type is 9.9E–01 at LANL in Regionalized 1; this value approaches the threshold value of 1.0 beyond which adverse health effects become more likely. All other hazard indices are below 1.0. The estimated annual frequency of occurrence for this accident type is "unlikely" for all sites and alternatives.

### D.3.3.8.6 *Risks to the Maximally Exposed Noninvolved Worker and Maximally Exposed Offsite Individual From Storage Facility Accidents*

**Accidents During Storage**. The highest hazard indices for the offsite MEI from an airplane impact affecting a storage facility or a storage facility fire are at ORR in Regionalized 1 and 2 (approximately 7.7E+01 and 2.4E+02, respectively); INEL in Regionalized 2 (approximately 3.7E+01); and LANL in Regionalized 1 (approximately 3.2E+01). The same trend holds true for the noninvolved worker MEI. At all three sites the controlling contaminant is mercury vapor.

Hazard indices associated with earthquake scenarios that affect storage facilities are usually less than 1.0 with the exception of the noninvolved worker MEI at ORR and INEL in Regionalized 2 (1.3 and 1.7, respectively). The hazard index from an earthquake-related accident is generally 2 to 3 orders of magnitude less than those associated with other storage facility accidents at the same site. In terms of annual accident frequency, earthquake and facility fire scenarios are considered "unlikely" (with the exception of the earthquake scenario at Hanford in Regionalized 1 which is considered "very unlikely"), while aircraft impacts are "extremely unlikely" to happen.

**Accidents During Treatment**. The highest hazard indices to the offsite MEI for all accident types are at ORR in Regionalized 1 and 2 (ranging from 3.5 to 1.1E+01); the aircraft impact and earthquake scenarios at INEL in Regionalized 2 (1.5 and 2.1, respectively); and the aircraft impact and earthquake scenarios at LANL in Regionalized 1 (1.3 and 1.0, respectively). The controlling contaminant at these sites is mercury vapor. The highest hazard indices to the noninvolved worker MEI are for all accident types at ORR in both alternatives (ranging from 3.7 to 1.1E+01); LANL in Regionalized 1 (ranging from 7.3 to 9.9); SRS in Regionalized 1 (4.4 for all accident types); and INEL in Regionalized 2 (ranging from 2.7 to 12). Each of these accidents, were it to occur, would result in exposures that might lead to adverse health effects to the MEIs. Recall, however, that the incinerator explosions are considered "anticipated," while the earthquake and aircraft impact scenarios are considered "very unlikely" and "extremely unlikely," respectively.

### D.3.3.8.7 *Risks to Waste Management Workers From Storage and Treatment Facility Accidents*

**Accidents During Storage**. The single-drum accident scenario resulting in the highest cancer incidence risk to workers (2.5E–03) is 5E, the forklift accident leading to a spill and fire with release of cadmium fumes (see Table D.3.3-13). The single-drum accident with the greatest risks to workers and involving the release of a noncarcinogen is 5F, a forklift accident resulting in a spill and fire with a release of dust from burnt and unburnt dichromate salts (analyzed as potassium dichromate). The IDLH index associated with this accident is 6.4E+01, which is 64 times the exposure concentration that could cause irreversible health effects if exposure were to last as long as 30 min. However, the accident scenario assumes a much shorter exposure duration, which could reduce the severity of health effects. For each site, the consequences of the maximum reasonably foreseeable single-drum accidents for workers are the same across alternatives. However, the estimated annual frequency of accident types 5E and 5F increases at ORR from "very

unlikely" in Regionalized 1 to "unlikely" in Regionalized 2. Note that the estimated annual frequency of 5F is zero (i.e., 5F is assumed not to occur) at SRS in Regionalized 1.

Storage facility fires and aircraft impacts with subsequent fires would pose very similar risks of cancer incidence and IDLH indices were they to occur at an site (see Tables D.3.3–16 and D.3.3–17). However, facility fires are projected to occur more frequently than airplane crashes ("unlikely" versus "extremely unlikely," respectively). Both cancer incidence risk and IDLH index increase by about 1 order of magnitude at INEL and ORR from Regionalized 1 to Regionalized 2 due to centralization of waste loads. The highest risk of cancer incidence is associated with the storage facility fire or aircraft crash at INEL in Regionalized 2 (1.4E–01 for each accident). The highest IDLH indices are also for the storage facility fire and aircraft crash at INEL in Regionalized 2 (5.1E+03 and 6.2E+03, respectively). These IDLH indices indicate that, were one of these accidents to occur, contaminant concentrations would greatly exceed the level considered immediately dangerous to life and health for exposures of 30 min. However, the accident scenarios assume a much shorter exposure duration, which could reduce the severity of health effects. The controlling contaminants at INEL are cadmium and mercury vapor.

Earthquake-related accidents result in IDLH indices greater than 1.0, but 2 to 3 orders of magnitude less than those resulting from other storage facility accidents. The highest IDLH index for earthquake-related releases from storage is also at INEL in Regionalized 2 (8.0). No carcinogens are assumed to be released in earthquake scenarios.

**Accidents During Treatment**. In both alternatives, cancer incidence risks to workers are similar among treatment accident types at a given site. However, similar to the trend for offsite and noninvolved worker populations, there is one exception: the incinerator explosion at SRS in Regionalized 1 results in a cancer incidence risk to workers of 5.0E–07; this is 3 orders of magnitude lower than other treatment facility accidents at SRS. As previously discussed, this is because there is no cadmium in the source term for the incinerator explosion. The highest site risks are for all accident types at ORR in both alternatives (ranging from 1.0E–03 to 2.0E–03) and INEL in Regionalized 2 (ranging from 1.3E–03 to 5.0E–03). The controlling contaminant is cadmium at both sites.

IDLH indices are similar among accident types at a given site in both alternatives. One notable exception is the incinerator explosion at Hanford in Regionalized 1, which results in an IDLH index approximately 1 order of magnitude lower than for other accident types. This is primarily because there is no cyanide in

the incinerator explosion source term (in contrast to the other accident types), since cyanide is converted to less toxic cyanates (ANL, 1996f). All IDLH indices associated with treatment facility accidents are greater than 1.0 by 1 to 3 orders of magnitude, indicating exposures to workers that could lead to irreversible health effects.

### D.3.4 TRANSURANIC WASTE

DOE Order 5820.2A defines transuranic waste (TRUW) as, "[w]ithout regard to source or form, waste that is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years, and concentrations greater than 100 nCi/g [nanocuries per gram] at the time of assay" (DOE, 1988). This lower activity limit is interpreted as being per gram of actual waste matrix, excluding the weight of added external shielding, liners, or packaging. By definition, TRUW includes neptunium, plutonium, americium, curium, and californium. DOE Order 5820.2A also provides for the management of some other alpha-contaminated wastes as TRUW, such as wastes containing uranium-233 and radium-226, as necessary. In this appendix the term "TRUW" refers to all materials meeting the DOE definition including TRUW that contain hazardous constituents regulated by the Resource Conservation and Recovery Act (RCRA). The principal focus of the PEIS is on TRUW generated since 1970, which has been packaged and retrievably stored in various trench, pit, vault, and pad configurations. (TRUW generated before 1970 was buried onsite in shallow landfills and may be addressed through environmental restoration activities.)

TRUW is generated primarily in research and development, weapons manufacturing, and plutonium recovery; some TRUW is also retrieved during environmental restoration and decontamination and decommissioning. DOE sites that generate or store TRUW (note that the abbreviations given here are used throughout this appendix) include the following:

- Argonne National Laboratory-East (ANL-E), Argonne, Illinois
- Argonne National Laboratory-West (ANL-W), Idaho Falls, Idaho
- Energy Technology Engineering Center (ETEC), Canoga Park, California
- Hanford Site (Hanford), Richland, Washington
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Inhalation Toxicology Research Institute (ITRI), Albuquerque, New Mexico
- Lawrence Berkeley Laboratory (LBL), Berkeley, California
- Lawrence Livermore National Laboratory (LLNL), Livermore, California

- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Mound Plant (Mound), Miamisburg, Ohio
- Nevada Test Site (NTS), Las Vegas, Nevada
- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee
- Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky
- Rocky Flats Environmental Technology Site (RFETS), Golden, Colorado
- Sandia National Laboratories-New Mexico (SNL-NM), Albuquerque, New Mexico
- Sandia National Laboratories-California (SNL-CA), Livermore, California
- Savannah River Site (SRS), Aiken, South Carolina
- University of Missouri (Columbia) (UofMO), Columbia, Missouri
- West Valley Demonstration Project (WVDP), West Valley, New York
- Waste Isolation Pilot Plant (WIPP), Carlsbad, New Mexico

This list includes the 12 major sites considered for TRUW management described in Section 8.4.1 of Volume I. Treatment risks were also estimated separately later in this section in Tables D.3.4–12 through D.3.4–17 for several other sites in addition to the 12 major TRUW management sites. Note that for the purposes of this risk analysis, the waste loads from three smaller generators were added to the inventories of larger generators. Specifically, the ITRI waste load was combined with the SNL-NM inventory, the ANL-W waste load was added to the INEL inventory, and the SNL-CA waste load was combined with the LLNL inventory. Also, source terms were not available for ETEC, UofMO, and WVDP, so risks at these installations were not evaluated (ANL, 1996b). Treatment risks at LBL and Mound are contained in the programwide risk tables (Tables D.3.4–6 through D.3.4–11) presented in this section of the WM PEIS and in the alternative summary risk tables presented in Section 8.4 of Volume I.

Most TRUW is solid waste (such as contaminated tools, machine parts, protective clothing, and laboratory glassware) but some is in liquid or sludge forms. Perhaps 50 to 60 % of the DOE inventory of TRUW is mixed waste, containing both radioactive and hazardous constituents regulated under RCRA. Examples of this mixed waste include sludges contaminated with spent solvents, debris contaminated with solvents and radionuclides, and discarded contaminated lead shielding. Depending on its chemical and physical properties, TRUW can be grouped into waste stream categories, such as aqueous liquids, organic liquids, solid process residues, soils, or debris, according to the type of treatment needed.

Packaged TRUW with a surface dose rate of less than 200 mrem/h is categorized as contact-handled TRUW (CH-TRUW). Packaged TRUW with a surface dose rate greater than 200 mrem/h emits sufficient penetrating beta, gamma, or neutron radiation to require remote handling, and is classified as remote-handled TRUW (RH-TRUW). The handling category determines the level of protective shielding needed to store and process the waste safely. The distinction between CH-TRUW and RH-TRUW is maintained in the human health risk analysis for both routine operations and accidents. Therefore, the results for CH-TRUW are presented separately from the results for RH-TRUW.

The DOE Waste Isolation Pilot Plant (WIPP), located near Carlsbad, New Mexico, has been identified as the permanent disposal site for DOE-generated TRUW. To ensure that TRUW can be disposed of safely at WIPP, DOE has developed a set of waste acceptance criteria (referred to as "WIPP-WAC" in the risk analysis tables) that waste generators and treatment and storage sites must meet before shipping TRUW to WIPP. These waste acceptance criteria were taken into account in developing the PEIS alternatives. However, because the final WIPP disposal criteria will likely be more stringent than current criteria, two additional treatment standards were evaluated in this analysis. The first of these was treatment to an intermediate waste form that generates less gas from the degradation of organic chemicals and corrodible metals than is mandated by current WIPP waste acceptance criteria. This is accomplished mainly by shredding and grouting the wastes and packaging them in containers that are not expected to release significant amounts of gases when disposed of at WIPP. The second was treatment to meet RCRA land disposal restrictions (LDRs) as promulgated in 1986 in Title 40, Chapter 268 of the Code of Federal Regulations. This is the most extensive of the three treatment standards; wastes are incinerated to destroy most of the hazardous organic chemical components. Inorganic components such as metals remain in ash after incineration. Small quantities of radioactive or hazardous constituents would be released into the environment from treatment facilities considered in this study. On the basis of the releases, human health risks were evaluated; the results are presented in this appendix.

Chapters 3 and 8 of the PEIS and the TRUW technical report (ANL, 1996b) provide more detailed information on this waste, including TRUW inventories at DOE sites, estimated release rates, treatment categories used in the PEIS, and the process for developing PEIS TRUW alternatives.

### D.3.4.1 Summary of CH-TRUW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized, and Centralized) and the rationale for developing the various CH-TRUW analysis alternatives are discussed rigorously in the main body of the PEIS.

- The No Action Alternative demonstrates the baseline risks of newly generated CH-TRUW packaging, certification, and indefinite interim storage at all generator sites. Treatment is not considered, and it is assumed that TRUW will not be disposed of at WIPP, although it will be prepared as though it were going to WIPP. The No Action Alternative does not assess the health risks, environmental impacts, or costs of removing TRUW from retrievable storage and packaging it.
- The Decentralized Alternative presents the risks of treating wastes to WIPP waste acceptance criteria and storing them at 10 sites.
- In Regionalized Alternative 1, CH-TRUW is consolidated, treated to minimize gas generation, and stored at five sites.
- In Regionalized Alternatives 2 and 3, CH-TRUW is consolidated, treated to meet RCRA LDRs, and stored at five and three sites, respectively.
- In the Centralized Alternative, CH-TRUW is consolidated, treated to meet RCRA LDRs, and stored at one site.

In Regionalized 1 and 2, consolidation, treatment, and storage take place at the same five sites. Comparison of these alternatives makes it possible to contrast the risks of treatment to minimize gas generation versus treatment to meet RCRA LDRs. Comparison of Regionalized 2, 3, and the Centralized Alternative demonstrates the differences in risks when the same treatment method is used but treatment and storage are performed at five, three, and one site(s), respectively.

Table D.3.4–1 presents the overall treatment and storage schemes for these six alternatives. Table D.3.4–2 shows which sites ship their wastes to regionalized or centralized consolidation sites for treatment and storage.

*Table D.3.4–1. PEIS Alternatives for CH-TRUW*

| Alternative | ANL-E | ETEC[a] | Hanford | INEL[b] | LANL | LBL | LLNL[c] | Mound | NTS | ORR | PGDP | RFETS | SNL-NM[d] | SRS | UofMO[a] | WVDP[a] | WIPP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | |
| No treatment/store at 16 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | |
| Decentralized Alternative | T | | T | T | T | | T | T | T | T | | T | | T | | | |
| Treat to WIPP-WAC/store at 10 | S | | S | S | S | | S | S | S | S | | S | | S | | | |
| Regionalized Alternative 1 | | | T | T | T | | | | | | | T | | T | | | |
| Treat to reduce gas/store at 5 | | | S | S | S | | | | | | | S | | S | | | |
| Regionalized Alternative 2 | | | T | T | T | | | | | | | T | | T | | | |
| Treat to LDRs/store at 5 | | | S | S | S | | | | | | | S | | S | | | |
| Regionalized Alternative 3 | | | T | T | | | | | | | | | | T | | | |
| Treat to LDRs/store at 3 | | | S | S | | | | | | | | | | S | | | |
| Centralized Alternative | | | | | | | | | | | | | | | | | T |
| Treat to LDRs/store at 1 | | | | | | | | | | | | | | | | | S |

Notes: T = treatment site. S = storage site.
[a] Data for ETEC, UofMO, and WVDP were not available so risks at these sites were not evaluated.
[b] Includes CH-TRUW from ANL-W.
[c] Includes CH-TRUW from SNL-CA.
[d] Includes CH-TRUW from ITRI.

***Table D.3.4–2. PEIS Consolidation and Treatment Strategies for CH-TRUW***

| Alternative | Origin | Treatment and Storage Destination |
|---|---|---|
| **No Action Alternative**<br>No treatment; store at 16 sites | All sites | Generators store own waste |
| **Decentralized Alternative**<br>Treat to WIPP-WAC and store at 10 sites | ANL-E<br>Hanford, LBL<br>INEL/ANL-W[a]<br>LANL, SNL-NM/ITRI[a]<br>LLNL/SNL-CA[a]<br>Mound, WVDP[b]<br>NTS, ETEC[c]<br>ORR, PGDP, UofMO[c]<br>RFETS<br>SRS | ANL-E<br>Hanford<br>INEL<br>LANL<br>LLNL<br>Mound<br>NTS<br>ORR<br>RFETS<br>SRS |
| **Regionalized Alternative 1**<br>Treat to minimize gas generation and store at 5 sites | Hanford, LBL, LLNL/SNL-CA<br>INEL/ANL-W, ETEC, NTS<br>LANL, SNL-NM/ITRI<br>RFETS<br>SRS, ANL-E, Mound, ORR, PGDP, UofMO, WVDP | Hanford<br>INEL<br>LANL<br>RFETS<br>SRS |
| **Regionalized Alternative 2**<br>Treat to RCRA LDRs and store at 5 sites | Hanford, LBL, LLNL/SNL-CA<br>INEL/ANL-W, ETEC, NTS<br>LANL, SNL-NM/ITRI<br>RFETS<br>SRS, ANL-E, Mound, ORR, PGDP, UofMO, WVDP | Hanford<br>INEL<br>LANL<br>RFETS<br>SRS |
| **Regionalized Alternative 3**<br>Treat to RCRA LDRs and store at 3 sites | Hanford, LBL, LLNL/SNL-CA<br>INEL/ANL-W, ETEC, LANL, NTS, RFETS, SNL-NM/ITRI<br>SRS, ANL-E, Mound, ORR, PGDP, UofMO, WVDP | Hanford<br>INEL<br>SRS |
| **Centralized Alternative**<br>Treat to RCRA LDRs and store at WIPP | All sites | WIPP |

[a] For the purpose of the human health risk analysis, the ANL-W waste load is added to the INEL inventory, the ITRI waste load is added to the SNL-NM inventory, and the SNL-CA waste load is added to the LLNL inventory.
[b] Source terms for WVDP were not available because the wastes at WVDP were special types that were not analyzed (see Section 8.2.1.1 of the WM PEIS). The new data in Appendix I shows some solid process residues and debris wastes, but in relatively small increments.
[c] Source terms for ETEC and UofMO were not evaluated (see Section 8.1.2 of the WM PEIS).

### D.3.4.2 Special Assumptions and Considerations Used in the TRUW Risk Analysis

For all alternatives except the No Action Alternative (for CH-TRUW and RH-TRUW), it is assumed that new facilities will be operational in the year 2003. All current inventory, retrievably stored waste, and waste generated between 1993 to 2013 will be treated from approximately 2003 to 2013. Waste generated after 2013 will be treated as necessary (ANL, 1996b). Therefore, all alternatives except No Action were evaluated to estimate human health risks for a 10-year period of treatment and storage, while No Action was evaluated for a 20-year period. Disposal risks were not estimated for TRUW since it is assumed that all TRUW will be disposed of at WIPP.

It is assumed that WIPP will accept TRUW for disposal from 1998 to 2018. The acceptance rate for waste will average 7,080 $m^3$/year (250,000 $ft^3$/year) for 20 years. Because WIPP waste acceptance criteria may change over time, the human health risk assessment was performed for treatment to three increasingly stringent standards to obtain a clearer picture of the full range of potential impacts, (current WIPP waste acceptance criteria, treatment for reduced gas generation, and RCRA LDRs).

In the No Action Alternative, wastes are retrieved where necessary, packaged, certified for shipment to WIPP, and placed in interim storage. There is no treatment of waste other than packaging, but health risks to public receptors and WM workers are assessed for retrieval and packaging operations. Retrieval potentially poses exposure risk due to emissions from corroding waste containers. Therefore, contaminant emissions during both retrieval and packaging were considered as part of routine waste management for TRUW.

Waste containers were assumed to be 55-gal drums for CH-TRUW; 6-in.-wall concrete casks for RH-TRUW; and Transuranic Package Transporter-II (TRUPACT II) containers for packaging wastes to be shipped to WIPP.

A hazard index is reported for the noninvolved worker MEI and offsite MEI, while an exposure index is reported for workers. The HI reflects the highest exposure of the noninvolved worker MEI and offsite MEI to noncarcinogenic, hazardous chemicals. The EI indicates the analogous exposure to an individual FTE.

Staffing requirements, expressed as FTEs, were estimated for the TRUW module for polymer solidification using the FTE data for grout solidification; and for the TRUW module for wet-air oxidation using the FTE

data for wet-air oxidation of alpha-contaminated LLW and LLMW. For more information on the treatment modules, see ORNL (1995b).

### D.3.4.3 Results Tables for the CH-TRUW Human Health Risk Analysis

This section contains the results tables for the CH-TRUW human health risk analysis. A discussion of the results is presented in Section D.3.4.4. The fatality and cancer incidence numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.4–3 presents an overview, by alternative, of the *total*, programwide risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers. This table provides the estimated *total number* of people in the three populations who will develop or die of cancers caused by exposure to CH-TRUW over the next 50 years if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities.
- Table D.3.4–4 shows the sizes of the total affected populations for each alternative.
- Table D.3.4–5 summarizes the risks to the noninvolved worker MEI and offsite MEI for each CH-TRUW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will die of cancer or develop cancer from radionuclide or chemical exposure, and indicators of the likelihood of suffering adverse health effects from exposure to noncarcinogenic, hazardous constituents.
- Tables D.3.4–6 through D.3.4–11 show the programwide risks for all receptors and health effect endpoints, by alternative.
- Tables D.3.4–12 through D.3.4–17 present offsite and worker population risks for each installation, by alternative.
- Table D.3.4–18 lists the radionuclides that contribute most of the risk of cancer fatality to the offsite population, by site and alternative.

***Table D.3.4–3. Summary of Programwide Risks Associated With Routine Management of CH-TRUW: Risks to Total Populations, by Alternative***

| Alternative | Offsite Population | | Noninvolved Worker Population | | WM Workers | | |
|---|---|---|---|---|---|---|---|
| | CF | CI | CF | CI | CF | CI | C&OF |
| No Action Alternative | 3.5E–05 | 1.2E–04 | 3.1E–06 | 1.1E–05 | 1.0E–01 | 3.4E–01 | 2.5E–01 |
| Decentralized Alternative | 1.6E–04 | 5.5E–04 | 1.4E–05 | 5.0E–05 | 6.1E–01 | 2.1 | 2.0 |
| Regionalized Alternative 1 | 2.6E–04 | 8.6E–04 | 2.4E–05 | 7.9E–05 | 6.2E–01 | 2.2 | 2.3 |
| Regionalized Alternative 2 | 8.7E–01 | 2.8 | 6.8E–02 | 2.9E–01 | 5.8E–01 | 2.0 | 3.6 |
| Regionalized Alternative 3 | 1.7E–01 | 6.5E–01 | 1.8E–02 | 7.8E–02 | 6.3E–01 | 2.2 | 2.9 |
| Centralized Alternative | 2.6E–01 | 8.9E–01 | 2.1E–02 | 7.2E–02 | 7.0E–01 | 2.5 | 1.6 |

Notes: CF = cancer fatality associated with radionuclide exposure; CI = cancer incidence associated with exposure to radionuclides and carcinogenic chemicals; C&OF = fatalities due to the physical hazards of constructing and operating waste management facilities.

***Table D.3.4–4. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of CH-TRUW, by Alternative***

| Alternative | Offsite | Noninvolved Worker | WM Worker |
|---|---|---|---|
| No Action | 27,716,666 | 70,681 | 1,696 |
| Decentralized | 28,643,318 | 92,462 | 6,485 |
| Regionalized 1 | 27,716,666 | 88,653 | 8,366 |
| Regionalized 2 | 27,716,666 | 88,653 | 14,047 |
| Regionalized 3 | 27,716,666 | 88,653 | 11,469 |
| Centralized | 27,861,555 | 89,713 | 8,238 |

***Table D.3.4–5. Summary of Programwide Risks Associated With Routine Management of CH-TRUW: Risks to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative***

| Alternative | Offsite MEI | | | | Noninvolved Worker MEI | | | |
|---|---|---|---|---|---|---|---|---|
| | CF | Rad CI | Chem CI | HI | CF | Rad CI | Chem CI | HI |
| No Action | 4.4E–10 | 1.3E–09 | 3.1E–13 | 2.6E–11 | 2.0E–09 | 6.9E–09 | 2.7E–10 | 1.2E–11 |
| Decentralized | 5.7E–09 | 1.9E–08 | 2.8E–12 | 1.6E–10 | 6.8E–09 | 2.3E–08 | 8.9E–12 | 1.4E–09 |
| Regionalized 1 | 6.9E–09 | 2.3E–08 | 4.8E–12 | 2.2E–10 | 1.3E–08 | 4.3E–08 | 1.5E–11 | 2.5E–09 |
| Regionalized 2 | 6.7E–05 | 2.3E–04 | 4.8E–12 | 1.1E–08 | 4.4E–05 | 1.5E–04 | 1.5E–11 | 2.8E–08 |
| Regionalized 3 | 5.1E–06 | 1.7E–05 | 4.8E–12 | 7.9E–10 | 1.4E–05 | 4.8E–05 | 1.5E–11 | 6.3E–09 |
| Centralized | 6.9E–05 | 2.3E–04 | 2.1E–13 | 4.9E–11 | 8.8E–05 | 2.8E–04 | 1.3E–12 | 3.0E–10 |

Notes: CF = cancer fatality associated with exposure to radionuclides; Rad CI = cancer incidence associated with exposure to radionuclides; Chem CI = cancer incidence associated with exposure to carcinogenic chemicals; HI = hazard index associated with exposure to noncarcinogenic, toxic chemicals.

***Table D.3.4–6. Programwide Risks Associated With Managing CH-TRUW Under the No Action Alternative***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 6.3E–03 | | | |
| | Cancer fatalities | 3.1E–06 | | | |
| | Cancer incidence | 1.1E–05 | 3.4E–09 | | |
| | Genetic effects | 6.3E–07 | | | |
| Noninvolved worker MEI | Dose (rem) | 4.1E–06 | | | |
| | Cancer fatalities | 2.0E–09 | | | |
| | Cancer incidence | 6.9E–09 | 2.7E–10 | | |
| | Genetic effects | 4.1E–10 | | | |
| | Hazard index | | | 1.2E–11 | |
| Offsite population | Dose (person-rem) | 7.0E–02 | | | |
| | Cancer fatalities | 3.5E–05 | | | |
| | Cancer incidence | 1.2E–04 | 1.4E–08 | | |
| | Genetic effects | 7.0E–06 | | | |
| Offsite MEI | Dose (rem) | 8.7E–07 | | | |
| | Cancer fatalities | 4.4E–10 | | | |
| | Cancer incidence | 1.5E–09 | 3.1E–13 | | |
| | Genetic effects | 8.7E–11 | | | |
| | Hazard index | | | 2.6E–11 | |
| WM workers | Dose (FTE-rem) | 2.5E+02 | | | |
| | Cancer fatalities | 1.0E–01 | | | |
| | Cancer incidence | 3.4E–01 | 2.8E–07 | | |
| | Genetic effects | 1.5E–02 | | | |
| | Exposure index | | | 2.1E–06 | |
| | Construction fatalities | | | | 1.1E–01 |
| | Construction injuries | | | | 4.2E–01 |
| | Operation fatalities | | | | 1.4E–01 |
| | Operation injuries | | | | 9.1E–01 |

***Table D.3.4–7. Programwide Risks Associated With Managing CH-TRUW Under the Decentralized Alternative***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 3.0E–02 | | | |
| | Cancer fatalities | 1.4E–05 | | | |
| | Cancer incidence | 5.0E–05 | 3.4E–08 | | |
| | Genetic effects | 3.0E–06 | | | |
| Noninvolved worker MEI | Dose (rem) | 1.4E–05 | | | |
| | Cancer fatalities | 6.8E–09 | | | |
| | Cancer incidence | 2.3E–08 | 8.9E–12 | | |
| | Genetic effects | 1.4E–09 | | | |
| | Hazard index | | | 1.4E–09 | |
| Offsite population | Dose (person-rem) | 3.2E–01 | | | |
| | Cancer fatalities | 1.6E–04 | | | |
| | Cancer incidence | 5.5E–04 | 1.3E–07 | | |
| | Genetic effects | 3.2E–05 | | | |
| Offsite MEI | Dose (rem) | 1.1E–03 | | | |
| | Cancer fatalities | 5.7E–09 | | | |
| | Cancer incidence | 1.9E–08 | 2.8E–12 | | |
| | Genetic effects | 1.1E–09 | | | |
| | Hazard index | 1.5E–10 | | 1.5E–10 | |
| WM workers | Dose (FTE-rem) | 1.5E+03 | | | |
| | Cancer fatalities | 6.1E–01 | | | |
| | Cancer incidence | 2.1 | 9.8E–06 | | |
| | Genetic effects | 9.1E–02 | | | |
| | Exposure index | | | 3.0E–05 | |
| | Construction fatalities | | | | 1.3 |
| | Construction injuries | | | | 5.0E+02 |
| | Operation fatalities | | | | 6.9E–01 |
| | Operation injuries | | | | 5.3E+02 |

***Table D.3.4–8. Programwide Risks Associated With Managing CH-TRUW Under Regionalized Alternative 1***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 4.6E–02 | | | |
| | Cancer fatalities | 2.4E–05 | | | |
| | Cancer incidence | 7.9E–05 | 5.6E–08 | | |
| | Genetic effects | 4.6E–06 | | | |
| Noninvolved worker MEI | Dose (rem) | 2.5E–05 | | | |
| | Cancer fatalities | 1.3E–08 | | | |
| | Cancer incidence | 4.3E–08 | 1.5E–11 | | |
| | Genetic effects | 2.5E–09 | | | |
| | Hazard index | | | 2.5E–09 | |
| Offsite population | Dose (person-rem) | 5.1E–01 | | | |
| | Cancer fatalities | 2.6E–04 | | | |
| | Cancer incidence | 8.6E–04 | 2.3E–07 | | |
| | Genetic effects | 5.1E–05 | | | |
| Offsite MEI | Dose (rem) | 1.4E–05 | | | |
| | Cancer fatalities | 6.9E–09 | | | |
| | Cancer incidence | 2.3E–08 | 4.8E–12 | | |
| | Genetic effects | 1.4E–09 | | | |
| | Hazard index | | | 2.2E–10 | |
| WM workers | Dose (FTE-rem) | 1.6E+03 | | | |
| | Cancer fatalities | 6.2E–01 | | | |
| | Cancer incidence | 2.2 | 1.8E–05 | | |
| | Genetic effects | 9.2E–02 | | | |
| | Exposure index | | | 2.4E–05 | |
| | Construction fatalities | | | | 1.5 |
| | Construction injuries | | | | 6.2E+02 |
| | Operation fatalities | | | | 8.1E–01 |
| | Operation injuries | | | | 5.9E+02 |

***Table D.3.4–9. Programwide Risks Associated With Managing CH-TRUW Under Regionalized Alternative 2***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 1.5E–02 | | | |
| | Cancer fatalities | 6.8E–02 | | | |
| | Cancer incidence | 2.9E–01 | 5.5E–08 | | |
| | Genetic effects | 1.5E–02 | | | |
| Noninvolved worker MEI | Dose (rem) | 8.7E–02 | | | |
| | Cancer fatalities | 4.4E–05 | | | |
| | Cancer incidence | 1.5E–04 | 1.5E–11 | | |
| | Genetic effects | 8.7E–06 | | | |
| | Hazard index | | | 2.8E–08 | |
| Offsite population | Dose (person-rem) | 1.9E+03 | | | |
| | Cancer fatalities | 8.7E–01 | | | |
| | Cancer incidence | 2.8 | 2.2E–07 | | |
| | Genetic effects | 1.9E–01 | | | |
| Offsite MEI | Dose (rem) | 1.3E–01 | | | |
| | Cancer fatalities | 6.7E–05 | | | |
| | Cancer incidence | 2.3E–04 | 4.8E–12 | | |
| | Genetic effects | 1.3E–05 | | | |
| | Hazard index | | | 1.1E–08 | |
| WM workers | Dose (FTE-rem) | 1.4E+03 | | | |
| | Cancer fatalities | 5.8E–01 | | | |
| | Cancer incidence | 2.0 | 2.4E–05 | | |
| | Genetic effects | 8.8E–02 | | | |
| | Exposure index | | | 2.1E–06 | |
| | Construction fatalities | | | | 2.2 |
| | Construction injuries | | | | 8.6E+02 |
| | Operation fatalities | | | | 1.4 |
| | Operation injuries | | | | 1.1E+03 |

***Table D.3.4–10. Programwide Risks Associated With Managing CH-TRUW Under Regionalized Alternative 3***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 3.6E+01 | | | |
| | Cancer fatalities | 1.8E–02 | | | |
| | Cancer incidence | 7.8E–02 | 5.6E–08 | | |
| | Genetic effects | 3.6E–03 | | | |
| Noninvolved worker MEI | Dose (rem) | 2.8E–02 | | | |
| | Cancer fatalities | 1.4E–05 | | | |
| | Cancer incidence | 4.8E–05 | 1.5E–11 | | |
| | Genetic effects | 2.8E–06 | | | |
| | Hazard index | | | 1.4E–10 | |
| Offsite population | Dose (person-rem) | 3.8E+02 | | | |
| | Cancer fatalities | 1.7E–01 | | | |
| | Cancer incidence | 6.5E–01 | 2.2E–07 | | |
| | Genetic effects | 3.8E–02 | | | |
| Offsite MEI | Dose (rem) | 1.0E–02 | | | |
| | Cancer fatalities | 5.1E–06 | | | |
| | Cancer incidence | 1.7E–05 | 4.8E–12 | | |
| | Genetic effects | 1.0E–06 | | | |
| | Hazard index | | | 7.9E–10 | |
| WM workers | Dose (FTE-rem) | 1.5E+03 | | | |
| | Cancer fatalities | 6.3E–01 | | | |
| | Cancer incidence | 2.2 | 3.5E–05 | | |
| | Genetic effects | 9.4E–02 | | | |
| | Exposure index | | | 2.1E–06 | |
| | Construction fatalities | | | | 1.8 |
| | Construction injuries | | | | 7.0E+02 |
| | Operation fatalities | | | | 1.1 |
| | Operation injuries | | | | 7.9E+02 |

***Table D.3.4–11. Programwide Risks Associated With Managing CH-TRUW Under the Centralized Alternative***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 4.2E–01 | | | |
| | Cancer fatalities | 2.1E–02 | | | |
| | Cancer incidence | 7.2E–02 | 6.3E–08 | | |
| | Genetic effects | 4.2E–03 | | | |
| Noninvolved worker MEI | Dose (rem) | 1.6E–01 | | | |
| | Cancer fatalities | 8.2E–05 | | | |
| | Cancer incidence | 2.8E–04 | 1.3E–12 | | |
| | Genetic effects | 1.6E–05 | | | |
| | Hazard index | | | 3.0E–10 | |
| Offsite population | Dose (person-rem) | 5.2E+02 | | | |
| | Cancer fatalities | 2.6E–01 | | | |
| | Cancer incidence | 8.9E–01 | 2.2E–07 | | |
| | Genetic effects | 5.0E–02 | | | |
| Offsite MEI | Dose (rem) | 1.4E–01 | | | |
| | Cancer fatalities | 6.9E–05 | | | |
| | Cancer incidence | 2.3E–04 | 2.1E–13 | | |
| | Genetic effects | 1.4E–05 | | | |
| | Hazard index | | | 4.9E–11 | |
| WM workers | Dose (FTE-rem) | 1.8E+03 | | | |
| | Cancer fatalities | 7.0E–01 | | | |
| | Cancer incidence | 2.5 | 5.1E–05 | | |
| | Genetic effects | 1.0E–01 | | | |
| | Exposure index | | | 5.1E–04 | |
| | Construction fatalities | | | | 1.1 |
| | Construction injuries | | | | 4.3E–02 |
| | Operation fatalities | | | | 5.0E–01 |
| | Operation injuries | | | | 4.0E+02 |

***Table D.3.4–12. Risks Associated With Managing CH-TRUW Under the No Action Alternative, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| Hanford | 377,645 / 457 | 4.6E–06 | 9.5E–11 | 9.2E–02 | 1.6E–05 | 3.2E–10 | 2.1E–01 |
| INEL | 153,061 / 55 | 2.6E–09 | 3.3E–13 | 1.1E–02 | 8.9E–09 | 1.1E–12 | 3.8E–06 |
| LBL | 5,856,829 / 0 | 4.8E–10 | 7.0E–15 | 3.4E–05 | 1.7E–09 | 2.5E–14 | 3.2E–12 |
| LLNL | 6,324,234 / 148 | 1.1E–06 | 1.8E–11 | 3.0E–02 | 3.8E–06 | 6.1E–11 | 2.5E–05 |
| LANL | 159,152 / 257 | 4.1E–06 | 4.4E–10 | 5.3E–02 | 1.4E–05 | 1.5E–09 | 1.2E–03 |
| PGDP | 500,502 / 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mound | 3,032,983 / 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| NTS | 14,266 / 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| RFETS | 2,171,877 / 353 | 3.0E–06 | 4.1E–11 | 7.3E–02 | 1.0E–05 | 1.4E–10 | 2.9E–04 |
| SNL-NM | 610,714 / 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SRS | 620,618 / 320 | 2.2E–05 | 2.0E–10 | 6.3E–02 | 7.4E–05 | 6.9E–10 | 1.3E–01 |
| ANL-E | 7,939,785 / 106 | 5.5E–07 | 3.1E–12 | 2.2E–02 | 1.9E–06 | 1.0E–11 | 3.3E–06 |
| Total | | 3.5E–05 | 4.4E–10 | 3.5E–01 | 1.2E–04 | 1.5E–09 | 3.4E–01 |

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

***Table D.3.4–13. Risks Associated With Managing CH-TRUW Under the Decentralized Alternative, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| ANL-E | 7,939,785 / 275 | 1.8E–06 | 9.9E–12 | 1.0E–01 | 6.1E–06 | 3.4E–11 | 3.0E–02 |
| INEL | 153,061 / 2,303 | 1.1E–06 | 1.4E–10 | 1.0 | 3.8E–06 | 4.8E–10 | 8.7E–01 |
| LBL | 5,856,829 / 1 | 6.3E–09 | 9.4E–14 | 8.4E–03 | 2.1E–08 | 3.2E–13 | 7.6E–09 |
| LLNL | 6,324,234 / 354 | 3.5E–06 | 5.7E–11 | 1.1E–01 | 1.2E–05 | 2.0E–10 | 2.0E–03 |
| LANL | 159,152 / 1,064 | 5.4E–05 | 5.7E–09 | 4.9E–01 | 1.8E–04 | 1.9E–08 | 5.0E–01 |
| ORR | 881,652 / 2 | 0.00 | 0.00 | 4.7E–04 | 0.00 | 0.00 | 7.9E–14 |
| Mound | 3,032,983 / 84 | 8.4E–07 | 4.8E–11 | 3.2E–02 | 2.9E–06 | 1.6E–10 | 4.8E–04 |
| NTS | 14,266 / 204 | 1.1E–10 | 3.0E–14 | 6.8E–02 | 3.9E–10 | 1.0E–13 | 7.3E–04 |
| PGDP | 500,502 / 15 | 3.5E–09 | 3.9E–13 | 1.3E–02 | 1.2E–08 | 1.3E–12 | 1.6E–06 |
| RFETS | 2,171,877 / 664 | 9.3E–06 | 1.3E–10 | 2.2E–01 | 3.2E–05 | 4.3E–10 | 2.7E–02 |
| SNL-NM | 610,714 / 2 | 2.7E–09 | 1.1E–13 | 8.7E–03 | 9.1E–09 | 3.6E–13 | 2.1E–08 |
| SRS | 620,618 / 550 | 7.2E–05 | 6.8E–10 | 1.5E–01 | 2.5E–04 | 2.3E–09 | 2.4E–01 |
| Hanford | 377,645 / 967 | 1.7E–05 | 3.5E–10 | 2.8E–01 | 5.7E–05 | 1.2E–09 | 4.4E–01 |
| Total | | 1.6E–04 | 5.7E–09 | 2.5 | 5.5E–04 | 1.9E–08 | 2.1 |

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

***Table D.3.4-14. Risks Associated With Managing CH-TRUW Under Regionalized Alternative 1, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| ANL-E | 7,939,785<br>121 | 1.5E-06 | 8.5E-12 | 4.5E-02 | 5.2E-06 | 2.9E-11 | 3.0E-02 |
| Hanford | 377,645<br>1,330 | 3.0E-05 | 6.1E-10 | 3.5E-01 | 1.0E-04 | 2.1E-09 | 4.5E-01 |
| INEL | 153,061<br>3,100 | 1.4E-06 | 1.8E-10 | 1.2 | 4.9E-06 | 6.0E-10 | 8.7E-01 |
| LBL | 5,856,829<br>1 | 9.8E-09 | 1.5E-13 | 1.8E-04 | 3.4E-08 | 5.0E-13 | 7.5E-09 |
| LLNL | 6,324,234<br>186 | 3.6E-06 | 5.9E-11 | 5.7E-02 | 1.3E-05 | 2.1E-10 | 2.0E-03 |
| LANL | 159,152<br>1,502 | 6.5E-05 | 6.9E-09 | 6.4E-01 | 2.2E-04 | 2.3E-08 | 5.0E-01 |
| PGDP | 500,502<br>8 | 5.3E-09 | 5.9E-13 | 2.5E-03 | 1.8E-08 | 2.0E-12 | 1.7E-06 |
| Mound | 3,032,983<br>47 | 1.5E-06 | 8.6E-11 | 1.4E-02 | 5.1E-06 | 2.9E-10 | 4.7E-04 |
| NTS | 14,266<br>137 | 1.5E-10 | 3.9E-14 | 4.2E-02 | 5.1E-10 | 1.3E-13 | 7.0E-04 |
| RFETS | 2,171,877<br>989 | 1.5E-05 | 2.0E-10 | 3.4E-01 | 5.1E-05 | 6.9E-10 | 2.7E-02 |
| SNL-NM | 610,714<br>1 | 3.5E-09 | 1.4E-13 | 4.5E-04 | 1.2E-08 | 4.8E-13 | 2.1E-08 |
| SRS | 620,618<br>944 | 1.4E-04 | 1.3E-09 | 2.2E-01 | 4.6E-04 | 4.3E-09 | 2.7E-01 |
| Total | | 2.6E-04 | 6.9E-09 | 3.0 | 8.6E-04 | 2.3E-08 | 2.2 |

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

***Table D.3.4–15. Risks Associated With Managing CH-TRUW Under Regionalized Alternative 2, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| ANL-E | 7,939,785 / 121 | 1.5E–06 | 8.5E–12 | 4.5E–02 | 5.2E–06 | 2.9E–11 | 3.0E–02 |
| Hanford | 377,645 / 2,150 | 1.7E–01 | 3.4E–06 | 4.3E–01 | 5.6E–01 | 1.2E–05 | 4.3E–01 |
| INEL | 153,061 / 5,364 | 7.3E–03 | 9.1E–07 | 1.8 | 2.5E–02 | 3.1E–06 | 8.3E–01 |
| LBL | 5,856,829 / 1 | 9.8E–09 | 1.5E–13 | 1.8E–04 | 3.4E–08 | 5.0E–13 | 7.5E–09 |
| LLNL | 6,324,234 / 186 | 3.6E–06 | 5.9E–11 | 5.7E–02 | 1.3E–05 | 2.1E–10 | 2.0E–03 |
| LANL | 159,152 / 2,772 | 6.4E–01 | 6.7E–05 | 9.6E–01 | 2.2 | 2.3E–04 | 4.8E–01 |
| PGDP | 500,502 / 8 | 5.3E–09 | 5.9E–13 | 2.5E–03 | 1.8E–08 | 2.0E–12 | 1.7E–06 |
| Mound | 3,032,983 / 47 | 1.5E–06 | 8.6E–11 | 1.4E–02 | 5.1E–06 | 2.9E–10 | 4.7E–04 |
| NTS | 14,266 / 137 | 1.5E–10 | 3.9E–14 | 4.2E–02 | 5.1E–10 | 1.3E–13 | 7.0E–04 |
| RFETS | 2,171,877 / 1,852 | 1.1E–01 | 1.5E–06 | 5.7E–01 | 3.7E–01 | 5.0E–06 | 2.5E–02 |
| SNL-NM | 610,714 / 1 | 3.5E–09 | 1.4E–13 | 4.5E–04 | 1.2E–08 | 4.8E–13 | 2.1E–08 |
| SRS | 620,618 / 1,408 | 2.3E–03 | 2.1E–08 | 2.6E–01 | 7.7E–03 | 7.2E–08 | 2.6E–01 |
| Total | | 8.7E–01 | 6.7E–05 | 4.2 | 2.8 | 2.3E–04 | 2.0 |

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

***Table D.3.4–16. Risks Associated With Managing CH-TRUW Under Regionalized Alternative 3, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| ANL-E | 7,939,785 / 121 | 1.5E–06 | 8.5E–12 | 4.5E–02 | 5.2E–06 | 2.9E–11 | 3.0E–02 |
| Hanford | 377,645 / 2,150 | 1.7E–01 | 3.4E–06 | 4.3E–01 | 5.6E–01 | 1.2E–05 | 4.3E–01 |
| INEL | 153,061 / 6,277 | 4.1E–02 | 5.1E–06 | 2.1 | 1.4E–01 | 1.7E–05 | 8.7E–01 |
| LBL | 5,856,829 / 1 | 9.8E–09 | 1.5E–013 | 1.8E–04 | 3.4E–08 | 5.0E–13 | 7.5E–09 |
| LLNL | 6,324,234 / 186 | 3.6E–06 | 5.9E–11 | 5.7E–02 | 1.3E–05 | 2.1E–10 | 2.0E–03 |
| LANL | 159,152 / 713 | 7.1E–05 | 7.4E–09 | 3.8E–01 | 2.4E–04 | 2.5E–08 | 5.0E–01 |
| PGDP | 500,502 / 8 | 5.3E–09 | 5.9E–13 | 2.5E–03 | 1.8E–08 | 2.0E–12 | 1.7E–06 |
| Mound | 3,032,983 / 47 | 1.5E–06 | 8.6E–11 | 1.4E–02 | 5.1E–06 | 2.9E–10 | 4.7E–04 |
| NTS | 14,266 / 137 | 1.5E–10 | 3.9E–14 | 4.2E–02 | 5.1E–10 | 1.3E–13 | 7.0E–04 |
| RFETS | 2,171,877 / 420 | 1.2E–05 | 1.6E–10 | 1.6E–01 | 4.1E–05 | 5.6E–10 | 1.0E–01 |
| SNL-NM | 610,714 / 1 | 3.5E–09 | 1.4E–13 | 4.5E–04 | 1.2E–08 | 4.8E–13 | 2.1E–08 |
| SRS | 620,618 / 1,408 | 2.3E–03 | 2.1E–08 | 2.6E–01 | 7.7E–03 | 7.2E–08 | 2.6E–01 |
| Total | | 1.7E–01 | 5.1E–06 | 3.5 | 6.5E–01 | 1.7E–05 | 2.2 |

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

***Table D.3.4–17. Risks Associated With Managing CH-TRUW Under the Centralized Alternative, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| WIPP | 99,889 / 4,132 | 2.6E–01 | 6.9E–05 | 4.6E–01 | 8.9E–01 | 2.3E–04 | 5.7E–02 |
| ANL-E | 7,939,785 / 121 | 1.5E–06 | 8.5E–12 | 4.5E–02 | 5.2E–06 | 2.9E–11 | 3.0E–02 |
| Hanford | 377,645 / 522 | 7.6E–06 | 1.6E–10 | 2.7E–01 | 2.6E–05 | 5.3E–10 | 5.6E–01 |
| INEL | 153,061 / 1,586 | 1.6E–06 | 2.0E–10 | 7.6E–01 | 5.3E–06 | 6.6E–10 | 8.5E–01 |
| LBL | 5,856,829 / 1 | 9.8E–09 | 1.5E–13 | 1.8E–04 | 3.4E–08 | 5.0E–13 | 7.5E–09 |
| LLNL | 6,324,234 / 186 | 3.6E–06 | 5.9E–11 | 5.7E–02 | 1.3E–05 | 2.1E–10 | 2.0E–03 |
| LANL | 159,152 / 713 | 7.1E–05 | 7.4E–09 | 3.8E–01 | 2.4E–04 | 2.5E–08 | 5.0E–01 |
| PGDP | 500,502 / 8 | 5.3E–09 | 5.9E–13 | 2.5E–03 | 1.8E–08 | 2.0E–12 | 1.7E–06 |
| Mound | 3,032,983 / 47 | 1.5E–06 | 8.6E–11 | 1.4E–02 | 5.1E–06 | 2.9E–10 | 4.7E–04 |
| NTS | 14,266 / 137 | 1.5E–10 | 3.9E–14 | 4.2E–02 | 5.1E–10 | 1.3E–13 | 7.0E–04 |
| RFETS | 2,171,877 / 420 | 1.2E–05 | 1.6E–10 | 1.6E–01 | 4.1E–05 | 5.6E–10 | 1.0E–01 |
| SNL-NM | 610,714 / 1 | 3.5E–09 | 1.4E–13 | 4.5E–04 | 1.2E–08 | 4.8E–13 | 2.1E–08 |
| SRS | 620,618 / 364 | 3.4E–05 | 3.2E–10 | 1.7E–01 | 1.2E–04 | 1.1E–09 | 3.6E–01 |
| Total | | 2.6E–01 | 6.9E–05 | 2.3 | 8.9E–01 | 2.3E–04 | 2.5 |

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

***Table D.3.4–18. CH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population at Each Site, by Alternative***

| Alternative | Installation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ANL-E | Hanford | INEL | LANL | LBL | LLNL | Mound | NTS | PGDP | RFETS | SNL-NM | SRS | ORR | WIPP |
| No Action | Pu-239[a] 4.21E-07[b] | Pu-238 3.05E-06 | Am-241 1.34E-09 | Am-241 2.14E-06 | Pu-239 2.53E-10 | Pu-239 5.68E-07 | Pu-238 0.00 | Pu-242 0.00 | Pu-242 0.00 | Am-241 1.59E-06 | Pu-242 0.00 | Pu-238 2.09E-05 | | |
| Decentralized | Pu-239 1.37E-06 | Pu-238 1.12E-05 | Am-241 5.84E-07 | Am-241 2.80E-05 | Pu-239 3.25E-09 | Pu-239 1.79E-06 | Pu-238 8.38E-07 | Pu-239 2.29E-10 | Pu-239 1.82E-09 | Am-241 4.94E-06 | Pu-239 1.38E-09 | Pu-238 6.95E-05 | Pu-242 0.00 | |
| Regionalized 1 | Pu-239 1.18E-06 | Pu-238 1.93E-05 | Am-241 7.39E-07 | Am-241 3.42E-05 | Pu-239 5.11E-09 | Pu-239 1.88E-06 | Pu-238 1.50E-06 | Pu-239 3.01E-10 | Pu-239 2.76E-09 | Am-241 7.94E-06 | Pu-239 1.81E-09 | Pu-238 1.29E-04 | | |
| Regionalized 2 | Pu-239 1.18E-06 | Pu-238 1.06E-01 | Am-241 3.80E-03 | Am-241 3.33E-01 | Pu-239 5.11E-09 | Pu-239 1.88E-06 | Pu-238 1.50E-06 | Pu-239 3.01E-10 | Pu-239 2.76E-09 | Am-241 5.82E-02 | Pu-239 1.81E-09 | Pu-238 1.65E-03 | | |
| Regionalized 3 | Pu-239 1.18E-06 | Pu-238 1.06E-01 | Am-241 2.13E-02 | Am-241 3.68E-05 | Pu-239 5.11E-09 | Pu-239 1.88E-06 | Pu-238 1.50E-06 | Pu-239 3.01E-10 | Pu-239 2.76E-09 | Am-241 6.45E-06 | Pu-239 1.81E-09 | Pu-238 1.65E-03 | | |
| Centralized | Pu-239 1.18E-06 | Pu-238 5.0E-06 | Am-241 8.11E-07 | Am-241 3.68E-05 | Pu-239 5.11E-09 | Pu-239 1.88E-06 | Pu-238 1.50E-06 | Pu-239 3.01E-10 | Pu-239 2.76E-09 | Am-241 6.45E-06 | Pu-239 1.81E-09 | Pu-238 3.28E-05 | | Pu-238 1.09E-01 |

[a] Radionuclide contributing most risk.
[b] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this site.

### D.3.4.4 Results of the CH-TRUW Human Health Risk Analysis for Routine Operations

In general, No Action presents the lowest health risks for all public and worker populations and for all health risk endpoints because no waste treatment is performed other than packaging. For offsite and noninvolved worker receptors, the health risks associated with the other CH-TRUW alternatives generally increase as more extensive waste treatment is assumed; the alternatives with the highest estimated health risks are those involving treatment to meet RCRA LDRs. For workers, all alternatives that include waste treatment involve similar health risks. Overall, the health risks from exposure to chemicals in CH-TRUW are considerably lower than from exposure to radionuclides. In addition, the probability of adverse effects from noncarcinogenic, hazardous chemicals is very low. Estimated impacts to each receptor population are summarized below.

#### D.3.4.4.1 *Programwide Trends in Human Health Risks Associated With CH-TRUW Management Alternatives*

**Offsite Population**. Radiological and chemical exposure risks to the offsite population are lowest for No Action in which CH-TRUW is stored, without treatment, at the 16 generator sites in existing or approved facilities. The programwide risk of cancer fatality for this alternative is 3.5E–05 distributed over a total affected offsite population of approximately 28 million (see Tables D.3.4–3 and D.3.4–4). The exposure risks to offsite populations in Decentralized (in which wastes are treated to WIPP waste acceptance criteria and stored at 10 installations) and Regionalized 1 (in which wastes are treated to reduce gas generation and stored at 5 installations) are slightly higher than those for No Action and are distributed over a similar total population. Regionalized 2, 3, and Centralized, the three alternatives in which CH-TRUW receives the extensive treatment necessary to meet RCRA LDRs, show markedly higher risks to offsite populations than other alternatives, with 0.17 to 0.87 estimated cancer fatalities over a total population of approximately 28 million people.

The highest risks to the offsite population are associated with Regionalized 2 and 3 (in which wastes are treated to RCRA LDRs and stored at five and three sites, respectively). Estimated programwide cancer fatalities for all 12 sites in Regionalized 2 and 3 are 0.87 and 0.17, respectively, for a total offsite population of approximately 28 million. Tables D.3.4–15 and D.3.4–16 show that the predominant portion of the estimated cancer risks in Regionalized 2 and 3 are attributed to LANL and Hanford, respectively.

At LANL, 0.64 cancer fatalities are estimated to occur in the Regionalized 2 Alternative, while 4.1E–02 cancer fatalities are estimated to occur in Regionalized 3. These fatalities are estimated to occur in a population of 159,152 over a 10-year treatment period. In both the Regionalized 2 and 3 Alternatives, 0.17 cancer fatalities in a population of 377,645 at Hanford are estimated to occur over the 10-year treatment period. The higher estimated cancer risks at Hanford and LANL are linked to their relatively large inventory of plutonium-238 and americium-241, respectively (the larger the contaminant inventory with respect to other sites, the larger the amount of contaminant assumed to be released during treatment).

The risks of radionuclide-related cancer incidence and genetic effects follow the same general trend as for cancer fatalities. Estimated programwide risk of cancer incidence due to exposure to carcinogenic chemicals remains fairly consistent (in the E–07 order of magnitude) across alternatives except for No Action in which this estimated risk is slightly lower by approximately 1 order of magnitude.

**Noninvolved Worker Population**. The programwide health risks to noninvolved worker populations parallel the trends observed for offsite populations but are slightly lower and involve much smaller affected populations (see Table D.3.4–4). Regionalized 2 poses the highest programwide risk to noninvolved worker populations (6.8E–02 total estimated cancer fatalities); however, the estimated cancer fatality risk for Regionalized 3 (1.8E–02) is only slightly lower than for Regionalized 2. The programwide risk of cancer incidence due to exposure to carcinogenic chemicals is in the E–08 order of magnitude in all except No Action, where it is slightly lower (by approximately 1 order of magnitude).

**Maximally Exposed Noninvolved Worker and Offsite Individual**. As shown in Table D.3.4–5, radiological exposure risks to the noninvolved worker and offsite MEIs are lowest for No Action, slightly higher for Decentralized and Regionalized 1, and highest by approximately 4 to 5 orders of magnitude for Regionalized 2, 3, and Centralized. This trend generally parallels that seen for noninvolved worker and offsite populations. The risk of cancer fatality for an MEI in Regionalized 2 and 3 are in the E–06 to E–05 range, and the highest risk of cancer fatality for an MEI is in the Centralized Alternative (8.8E–05 for the noninvolved worker MEI and 6.9E–05 for the offsite MEI). In the alternatives involving treatment to LDRs (Regionalized 2, 3, and Centralized), the risks of cancer incidence to the noninvolved worker and offsite MEIs from radionuclides exceed 1.0E–04.

Tables D.3.4–15 through D.3.4–17 show that the highest risks of cancer fatality to the offsite MEI are at LANL, Hanford, and RFETS in Regionalized 2; Hanford and INEL in Regionalized 3; and WIPP in the

Centralized Alternative. The elevated risks to the MEIs at these sites are due to two factors. First, in Regionalized 2 and 3, elevated cancer risks to the MEIs at LANL, Hanford, and RFETS result from increased exposure to emissions during treatment to LDRs. Second, in Regionalized 3 and Centralized, elevated cancer risks to the MEIs at INEL and WIPP result from a combination of increased emissions from treatment to LDRs and increased waste loads from consolidation.

All health risks due to chemical exposures are relatively low compared to radiation risks. Estimated risk of cancer incidence to each MEI due to chemical exposure is similar among alternatives and does not exceed the E-11 order of magnitude. In addition, the hazard indices for both MEIs are at least 9 orders of magnitude below 1.0 in all alternatives, indicating that adverse health effects from noncarcinogenic chemicals are unlikely.

**Workers**. As observed for public receptor populations, programwide radiological and chemical exposure risks to workers are lowest in No Action. Worker health risks for No Action are lower than for the other alternatives by approximately 1 order of magnitude (1.0E-01 estimated cancer fatalities over a population of 1,696 FTEs). No treatment is performed and fewer FTEs are required than in the other alternatives, resulting in less collective exposure. The estimated risk of cancer fatality (approximately 6.0E-01) and cancer incidence (approximately 2.0) due to radiation exposure are approximately equal in all but No Action, indicating that collective worker radiation exposure is relatively independent of the type of CH-TRUW treatment involved.

Worker health risks associated with chemical exposure vary slightly among alternatives. The exposure index, or the highest individual worker exposure to noncarcinogenic chemicals, follows the trend for the noninvolved worker and offsite MEIs (No Action is the lowest; Decentralized and Regionalized 1 are slightly higher; and Regionalized 2, 3, and Centralized are substantially higher). However, the exposure indices in all alternatives are at least 5 orders of magnitude below 1.0, indicating a low probability of adverse health effects from noncarcinogenic, hazardous constituents. The risk of worker cancer incidence from chemical exposure rises gradually across alternatives (lowest in No Action and slightly higher in the other alternatives). As seen with public receptor populations, chemical exposure contributes much less to worker health risk estimates than radiation exposure.

Estimated construction and operational fatalities are always higher than those associated with radiation exposure, regardless of alternative. No Action results in lower worker health risks from physical hazards because fewer person-hours are spent in construction and operation of facilities; therefore, injuries and fatalities are less likely. Regionalized 2 poses the highest risk of construction and operation fatalities of all the alternatives (3.6), reflecting the greatest number of person-hours devoted to these activities (see Table D.3.4–4).

**Discussion**. Radiation exposure risks from the routine management of CH-TRUW are substantially greater for all populations than chemical exposure risks; in addition, risks of worker fatalities due to physical hazards are always greater than those due to exposure.

For the offsite population, SRS consistently poses the highest estimated cancer fatalities for the No Action, Decentralized, and Regionalized 1 Alternatives. For the Regionalized 2, Regionalized 3, and Centralized Alternatives, LANL, Hanford, and WIPP pose the highest estimated cancer fatalities. The radionuclides contributing the most risk to the offsite population at Hanford and LANL in Regionalized 2 and 3 are americium and plutonium isotopes through inhalation and ingestion (see Table D.3.4–18). The controlling radionuclides are the same at WIPP in the Centralized Alternative, reflecting the consolidation of all installations' CH-TRUW at WIPP. Note that the cancer fatality risk to the offsite population is more than 4 orders of magnitude higher when Hanford treats its own waste than when its waste is treated at WIPP. This reflects the larger size and higher density of the population surrounding Hanford (compare the population distributions for Hanford and WIPP as shown in Tables D.3.4–19 and D.3.4–20).

For workers, the highest estimated total fatalities (cancer fatalities plus construction and operational fatalities) are associated with INEL in every alternative except No Action, where Hanford has the highest worker fatality risks, and Centralized, where WIPP has the highest number of total fatalities. As might be expected, for each alternative, the installation with the highest worker risk also has the highest number of FTEs involved in CH-TRUW management. The radionuclides contributing the most risk for workers at these sites are uranium-238 and uranium-235 at INEL via inhalation; and cesium-137 at Hanford and WIPP via external exposure.

*Table D.3.4–19. Population Distribution Around Hanford on the Basis of the 1990 U.S. Census*

| Direction From Site | Distance From Site | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.8 km | 2.4 km | 4.0 km | 5.6 km | 7.2 km | 12 km | 24 km | 40 km | 56 km | 72 km | Total |
| S | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3,063.00 | 1,277.00 | 211.00 | 3,006.00 | 7,557.00 |
| SSW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 303.00 | 8,841.00 | 138.00 | 202.00 | 9,484.00 |
| SW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 24.00 | 25,654.00 | 4,298.00 | 90.00 | 30,066.00 |
| WSW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 35.00 | 2,012.00 | 18,451.00 | 5,004.00 | 25,502.00 |
| W | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 23.00 | 38.00 | 2,833.00 | 101,475.00 | 104,369.00 |
| WNW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 764.00 | 159.00 | 0.00 | 3,669.00 | 4,592.00 |
| NW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 299.00 | 1,405.00 | 114.00 | 460.00 | 2,278.00 |
| NNW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 284.00 | 516.00 | 1,030.00 | 5,804.00 | 7,634.00 |
| N | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2,121.00 | 369.00 | 2,003.00 | 4,493.00 |
| NNE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 75.00 | 721.00 | 3,623.00 | 19,894.00 | 24,313.00 |
| NE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 55.00 | 8,779.00 | 2,491.00 | 369.00 | 11,694.00 |
| ENE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 571.00 | 703.00 | 2,371.00 | 187.00 | 3,832.00 |
| E | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1,377.00 | 844.00 | 125.00 | 294.00 | 2,640.00 |
| ESE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 678.00 | 995.00 | 207.00 | 271.00 | 2,151.00 |
| SE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 183.00 | 42,497.00 | 55,888.00 | 297.00 | 98,865.00 |
| SSE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2,342.00 | 28,710.00 | 556.00 | 6,567.00 | 38,175.00 |
| Total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10,076.00 | 125,272.00 | 92,705.000 | 149,592.00 | 377,645.00 |

*Table D.3.4–20. Population Distribution Around the Waste Isolation Pilot Plant (WIPP) on the Basis of the 1990 U.S. Census*

| Direction From Site | Distance From Site | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.8 km | 2.4 km | 4.0 km | 5.6 km | 7.2 km | 12 km | 24 km | 40 km | 56 km | 72 km | Total |
| S | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 2.00 | 46.00 | 20.00 | 71.00 |
| SSW | 9.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 43.00 | 8.00 | 62.00 |
| SW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 37.00 | 57.00 | 0.00 | 5.00 | 99.00 |
| WSW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1,622.00 | 191.00 | 57.00 | 62.00 | 1,932.00 |
| W | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 138.00 | 25,291.00 | 197.00 | 3.00 | 25,629.00 |
| WNW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 38.00 | 5,765.00 | 242.00 | 63.00 | 6,108.00 |
| NW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.00 | 7.00 | 14.00 | 12,401.00 | 12,428.00 |
| NNW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.00 | 4.00 | 66.00 | 104.00 | 56.00 | 239.00 |
| N | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 63.00 | 12.00 | 78.00 |
| NNE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.00 | 3.00 | 122.00 | 7,353.00 | 7,482.00 |
| NE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 11.00 | 37.00 | 9,115.00 | 9,163.00 |
| ENE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 282.00 | 30,877.00 | 31,169.00 |
| E | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.00 | 5.00 | 2,982.00 | 19.00 | 3,012.00 |
| ESE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 16.00 | 2,173.00 | 97.00 | 2,286.00 |
| SE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 20.00 | 35.00 |
| SSE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 3.00 | 14.00 | 5.00 | 73.00 | 96.00 |
| TOTAL | 9.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 1,864.00 | 31,440.00 | 6,382.00 | 60,184.00 | 99,889.00 |

### D.3.4.4.2 *Comparison of the Decentralized Alternative and Regionalized Alternative 1: Treatment to WIPP Waste Acceptance Criteria Versus Treatment to Reduce Gas Generation*

A comparison of the Decentralized Alternative, in which CH-TRUW is stored and treated to WIPP waste acceptance criteria at 10 installations, and Regionalized 1, in which CH-TRUW is stored and treated to reduce gas generation at five installations, shows few differences in the health risks associated with these two treatment and consolidation options. The major difference between treating to WIPP waste acceptance criteria and treating to reduce gas generation is the addition of a waste shredding step in Regionalized 1, therefore, treatment risks should not be substantially different. The number of installations at which waste is consolidated also does not greatly affect the overall health risks.

### D.3.4.4.3 *Comparison of Regionalized Alternatives 1 and 2: Treatment to Reduce Gas Generation Versus Treatment to Meet Land Disposal Restrictions*

A more controlled comparison of treatment risks can be made between Regionalized 1 and 2 since consolidation schemes are identical (wastes are treated and stored at the same five sites in both alternatives) but treatments differ (treatment to reduce gas generation in Regionalized 1 versus treatment to LDRs in Regionalized 2). As previously noted, the programwide risks of cancer fatalities, cancer incidence, and genetic effects from radiation exposure associated with treatment to LDRs in Regionalized 2 are approximately 3 orders of magnitude greater for the offsite and noninvolved worker populations and MEIs than the risks from treatment for minimization of gas generation in Regionalized 1. While these radionuclide-related health effects differ between the two alternatives, the contribution of chemical carcinogens to cancer incidence is almost the same in each alternative for each population.

The programwide risks to workers from radionuclide exposure are nearly the same in Regionalized 1 and 2. In addition, the risk of chemical-related cancer incidence in workers is nearly identical between alternatives. This reflects the fact that collective worker exposure is similar between the alternatives, regardless of the different treatment options.

The offsite and noninvolved worker MEI hazard indices for Regionalized 2 are approximately 1 order of magnitude higher than in Regionalized 1, and the Regionalized 2 worker exposure index is about 1 order of magnitude higher than in Regionalized 1. This trend reflects the potential for higher individual exposure

to noncarcinogenic hazardous chemicals when CH-TRUW is treated to LDRs. However, in all alternatives, exposures to noncarcinogenic, hazardous chemicals yield hazard indices well below 1.0.

#### D.3.4.4.4 *Comparison of the Regionalized 2, 3, and Centralized Alternatives: Differences in Consolidation Configuration*

Examination of the Regionalized 2 and Centralized Alternatives provides a comparison of consolidation and interim storage configurations; in these three alternatives, wastes are treated to LDRs but are consolidated and stored at five, three, and one site(s), respectively. As discussed above, the programwide radiation exposure risks to all populations are very similar across all three alternatives with certain exceptions: In the Centralized Alternative, the risk of cancer fatality, cancer incidence, and genetic effects to offsite populations is less than 1 order of magnitude lower than the risks in Regionalized 2 and 3 because of the smaller population size and lower population density at WIPP compared to sites such as LANL, INEL, and Hanford. Also, the population at only one site, rather than several, is being exposed. However, the risks to the offsite and noninvolved worker MEIs are slightly higher in the Centralized Alternative than in Regionalized 2 and 3. These higher risks could be due to a combination of factors including the proximity of neighboring ranches to WIPP and the influence of weather conditions such as wind speed and direction. As previously noted, the estimated cancer incidence risks to the offsite and noninvolved worker MEIs are 2.3E–04 and 2.8E–04, respectively.

Risk of cancer incidence due to chemical exposure is within the same order of magnitude for all public receptor populations in all three alternatives. The hazard index for the offsite MEI in Regionalized 3 is slightly lower than the Regionalized 2 or Centralized estimates.

Worker radiation and chemical exposure risks are similar among the Regionalized 2, 3, and Centralized Alternatives.

#### D.3.4.4.5 *Summary of the Human Health Risk Analysis for Routine Management of CH-TRUW*

In summary, the No Action Alternative presents the fewest health risk to all populations. Health risks generally increase for the public receptors as more extensive treatment of CH-TRUW is assumed. Overall health risks to workers do not differ appreciably with different treatment options. The primary risk drivers for the public receptor populations are radiation exposure (as opposed to chemical exposure) and treatment option. For workers, the primary risk drivers are the size of the waste load and the person-hours necessary to process it.

### D.3.4.5 Summary of RH-TRUW Alternatives

The PEIS waste management alternatives (No Action, Decentralization, Regionalization, and Centralization) and the rationale for developing the various RH-TRUW analysis alternatives are discussed rigorously in the main body of the PEIS. Four alternatives are analyzed for the RH-TRUW human health risk analysis:

- The No Action Alternative demonstrates the baseline risks of RH-TRUW retrieval, packaging, certification, and indefinite interim storage at ANL-E, Hanford, INEL, LANL, ORR and SRS. Treatment is not considered and it is assumed that TRUW will not be disposed of at WIPP.
- In the Decentralized Alternative, risks are estimated for building additional treatment facilities as required, treating wastes to WIPP waste acceptance criteria, and storing them at the six sites pending disposal at WIPP.
- In the Regionalized Alternative 1, RH-TRUW is consolidated, treated to minimize gas generation, and stored at Hanford and ORR.
- In the Regionalized 2, 3, and Centralized Alternatives, RH-TRUW is consolidated, treated to meet RCRA LDRs, and stored at Hanford and ORR. (This scenario makes it possible to contrast the risks of different levels of treatment of RH-TRUW by comparison with Regionalized Alternative 1.)

Table D.3.4–21 presents the overall treatment and storage schemes for these RH-TRUW alternatives. Table D.3.4–22 shows which sites will ship their wastes to regionalized or centralized consolidation sites for treatment and storage. Note that for the purposes of this risk analysis, the waste load from a smaller generator, ANL-W, was added to the inventory of INEL, a larger generator (ANL, 1996b), as the two sites are in close proximity to one another.

The discussion of the risk analysis results will address the overall health risk trends across the alternatives discussed above, comparisons among alternatives, higher-risk sites and alternatives, and major factors driving the estimated risks.

*Table D.3.4–21. PEIS Alternatives for RH-TRUW*

| Alternative | ANL-E | Hanford | INEL | LANL | ORR | SRS |
|---|---|---|---|---|---|---|
| **No Action Alternative** No treatment; store at 6 sites | T | T | T | T | T | T |
| | S | S | S | S | S | S |
| **Decentralized Alternative** Treat to WIPP-WAC and store at 6 sites | T | T | T | T | T | T |
| | S | S | S | S | S | S |
| **Regionalized Alternative 1** Treat to reduce gas and store at 2 sites | | T | | | T | |
| | | S | | | S | |
| **Regionalized Alternatives 2, 3, and Centralized Alternative** Treat to RCRA LDRs and store at 2 sites | | T | | | T | |
| | | S | | | S | |

Notes: T = treatment installation; S = storage installation.

*Table D.3.4–22. PEIS Consolidation and Treatment Strategies for RH-TRUW*

| Alternative | Origin | Treatment and Storage Destination |
|---|---|---|
| **No Action Alternative** No treatment; store at 6 sites | All sites | Generators store own waste |
| **Decentralized Alternative** Treat to WIPP-WAC and store at 6 sites | All sites | Generators treat and store own waste |
| **Regionalized Alternative 1** Treat to minimize gas generation and store at 2 sites | Hanford, INEL/ANL-W[a], LANL, ORR, ANL-E, SRS | Hanford<br>ORR |
| **Regionalized Alternatives 2, 3, and Centralized Alternative** Treat to RCRA LDRs and store at 2 sites | Hanford, INEL/ANL-W[a], LANL, ORR, ANL-E, SRS | Hanford<br>ORR |

[a] For the purpose of the human health risk analysis, the ANL-W waste load is added to the INEL waste load.

### D.3.4.6 Results Tables for the RH-TRUW Human Health Risk Analysis

This section contains the results tables for the RH-TRUW human health risk analysis. A discussion of the results is presented in Section D.3.4.7. The fatality and cancer incidence numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.4–23 presents an overview, by alternative, of the *total*, programwide risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers. These tables provide the estimated *total number* of people in the three populations who will develop or die of cancers caused by exposure to RH-TRUW if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities.
- Table D.3.4–24 shows the sizes of the total affected populations for each alternative.
- Table D.3.4–25 summarizes the risks to the noninvolved worker MEI and offsite MEI for each RH-TRUW alternative. The numbers in this table are the estimated *probabilities* that the noninvolved worker and offsite MEIs will die of or develop cancer from radionuclide or chemical exposure, or indicators of the likelihood of suffering adverse health effects from exposure to noncarcinogenic, hazardous constituents.
- Tables D.3.4–26 through D.3.4–29 show the programwide risks for all receptors and health effect endpoints, by alternative.
- Tables D.3.4–30 through D.3.4–33 present offsite and worker population risks for each installation, by alternative.
- Table D.3.4–34 lists the radionuclides that contribute most of the risk to the offsite population, by installation and alternative.

***Table D.3.4–23. Summary of Programwide Risks Associated With Routine Management of RH-TRUW: Risks to Total Populations, by Alternative***

| Alternative | Offsite Population | | Noninvolved Worker Population | | WM Workers | | |
|---|---|---|---|---|---|---|---|
| | CF | CI | CF | CI | CF | CI | C&OF |
| No Action | 2.8E–06 | 9.6E–06 | 1.3E–07 | 4.3E–07 | 6.2E–02 | 2.2E–01 | 7.1E–02 |
| Decentralized | 7.4E–06 | 2.5E–05 | 3.3E–07 | 1.1E–06 | 4.3E–03 | 1.5E–02 | 3.0E–01 |
| Regionalized 1 | 1.3E–05 | 4.3E–05 | 5.7E–07 | 1.9E–06 | 6.2E–03 | 2.2E–02 | 3.3E–01 |
| Regionalized 2, 3, and Centralized | 4.6E–02 | 1.6E–01 | 1.6E–03 | 5.4E–03 | 9.6E–02 | 3.4E–01 | 4.6E–01 |

Notes: CF = cancer fatality associated with radionuclide exposure; CI = cancer incidence associated with exposure to radionuclides and carcinogenic chemicals; C&OF = fatalities due to the physical hazards of constructing and operating waste management facilities.

***Table D.3.4–24. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of RH-TRUW, by Alternative***

| Alternative | Offsite | Noninvolved Worker | WM Worker |
|---|---|---|---|
| No Action | 10,131,913 | 38,057 | 59 |
| Decentralized | 10,131,913 | 38,057 | 1,109 |
| Regionalized 1 | 10,131,913 | 38,057 | 1,469 |
| Regionalized 2, 3, and Centralized | 10,131,913 | 38,057 | 2,326 |

***Table D.3.4–25. Summary of Programwide Risks Associated With Routine Management of RH-TRUW: Risks to the Maximally Exposed Offsite Individual and Maximally Exposed Noninvolved Worker, by Alternative***

| Alternative | Offsite MEI | | | | Noninvolved Worker MEI | | | |
|---|---|---|---|---|---|---|---|---|
| | CF | Rad CI | Chem CI | HI | CF | Rad CI | Chem CI | HI |
| No Action | 5.5E–11 | 1.9E–10 | 4.0E–13 | 3.5E–12 | 2.1E–10 | 7.2E–10 | 2.5E–12 | 2.8E–11 |
| Decentralized | 1.3E–10 | 4.5E–10 | 8.1E–12 | 1.3E–10 | 5.1E–10 | 1.7E–09 | 5.0E–11 | 8.0E–10 |
| Regionalized 1 | 2.4E–10 | 8.3E–10 | 8.1E–12 | 1.3E–10 | 9.2E–10 | 3.1E–09 | 5.1E–11 | 7.7E–10 |
| Regionalized 2, 3, and Centralized | 1.3E–06 | 4.4E–06 | 5.7E–12 | 1.8E–09 | 1.1E–06 | 3.6E–06 | 3.5E–11 | 9.3E–09 |

Notes: CF = cancer fatality associated with exposure to radionuclides; Rad CI = cancer incidence associated with exposure to radionuclides; Chem CI = cancer incidence associated with exposure to carcinogenic chemicals; HI = hazard index associated with exposure to noncarcinogenic, toxic chemicals.

***Table D.3.4–26. Programwide Risks Associated With Treatment of RH-TRUW Under the No Action Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 2.5E–04 | | | |
| | Cancer fatalities | 1.3E–07 | | | |
| | Cancer incidence | 4.3E–07 | 2.6E–09 | | |
| | Genetic effects | 2.5E–08 | | | |
| Noninvolved worker MEI | Dose (rem) | 4.3E–07 | | | |
| | Cancer fatalities | 2.1E–10 | | | |
| | Cancer incidence | 7.2E–10 | 2.5E–12 | | |
| | Genetic effects | 4.3E–11 | | | |
| | Hazard index | | | 2.8E–11 | |
| Offsite population | Dose (person-rem) | 5.7E–03 | | | |
| | Cancer fatalities | 2.8E–06 | | | |
| | Cancer incidence | 9.6E–06 | 8.1E–09 | | |
| | Genetic effects | 5.7E–07 | | | |
| Offsite MEI | Dose (rem) | 1.1E–07 | | | |
| | Cancer fatalities | 5.5E–11 | | | |
| | Cancer incidence | 1.9E–10 | 4.0E–13 | | |
| | Genetic effects | 1.1E–11 | | | |
| | Hazard index | | | 3.5E–12 | |
| WM workers | Dose (FTE-rem) | 1.5E+02 | | | |
| | Cancer fatalities | 6.2E–02 | | | |
| | Cancer incidence | 2.2E–01 | 9.0E–08 | | |
| | Genetic effects | 9.3E–03 | | | |
| | Exposure index | | | 3.7E–06 | |
| | Construction fatalities | | | | 3.5E–02 |
| | Construction injuries | | | | 1.1E+01 |
| | Operation fatalities | | | | 3.6E–02 |
| | Operation injuries | | | | 1.6E–01 |

***Table D.3.4–27. Programwide Risks Associated With Treatment of RH-TRUW Under the Decentralized Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 6.4E–04 | | | |
| | Cancer fatalities | 3.3E–07 | | | |
| | Cancer incidence | 1.1E–06 | 5.2E–08 | | |
| | Genetic effects | 6.4E–08 | | | |
| Noninvolved worker MEI | Dose (rem) | 1.0E–06 | | | |
| | Cancer fatalities | 5.0E–10 | | | |
| | Cancer incidence | 1.7E–09 | 5.0E–11 | | |
| | Genetic effects | 1.0E–10 | | | |
| | Hazard index | | | 8.0E–10 | |
| Offsite population | Dose (person-rem) | 1.5E–02 | | | |
| | Cancer fatalities | 7.4E–06 | | | |
| | Cancer incidence | 2.5E–05 | 1.6E–07 | | |
| | Genetic effects | 1.5E–06 | | | |
| Offsite MEI | Dose (rem) | 2.7E–07 | | | |
| | Cancer fatalities | 1.3E–10 | | | |
| | Cancer incidence | 4.5E–10 | 8.1E–12 | | |
| | Genetic effects | 2.7E–11 | | | |
| | Hazard index | | | 1.3E–10 | |
| WM workers | Dose (FTE-rem) | 1.1E+01 | | | |
| | Cancer fatalities | 4.3E–03 | | | |
| | Cancer incidence | 1.5E–02 | 3.0E–06 | | |
| | Genetic effects | 6.3E–04 | | | |
| | Exposure index | | | 3.1E–05 | |
| | Construction fatalities | | | | 2.0E–01 |
| | Construction injuries | | | | 7.8E+01 |
| | Operation fatalities | | | | 1.0E–01 |
| | Operation injuries | | | | 6.7E+01 |

***Table D.3.4–28. Programwide Risks Associated With Treatment of RH-TRUW Under Regionalized Alternative 1, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 1.1E–03 | | | |
| | Cancer fatalities | 5.7E–07 | | | |
| | Cancer incidence | 1.9E–06 | 5.2E–08 | | |
| | Genetic effects | 1.1E–07 | | | |
| Noninvolved worker MEI | Dose (rem) | 1.9E–06 | | | |
| | Cancer fatalities | 9.3E–10 | | | |
| | Cancer incidence | 3.1E–09 | 5.0E–11 | | |
| | Genetic effects | 1.9E–10 | | | |
| | Hazard index | | | 8.0E–10 | |
| Offsite population | Dose (person-rem) | 2.6E–02 | | | |
| | Cancer fatalities | 1.3E–05 | | | |
| | Cancer incidence | 4.3E–05 | 1.6E–07 | | |
| | Genetic effects | 2.6E–06 | | | |
| Offsite MEI | Dose (rem) | 4.9E–07 | | | |
| | Cancer fatalities | 2.4E–10 | | | |
| | Cancer incidence | 8.3E–10 | 8.1E–12 | | |
| | Genetic effects | 4.9E–11 | | | |
| | Hazard index | | | 1.3E–10 | |
| WM workers | Dose (FTE-rem) | 1.6E+01 | | | |
| | Cancer fatalities | 6.2E–03 | | | |
| | Cancer incidence | 2.2E–02 | 3.4E–06 | | |
| | Genetic effects | 9.3E–04 | | | |
| | Exposure index | | | 3.1E–05 | |
| | Construction fatalities | | | | 2.3E–01 |
| | Construction injuries | | | | 7.8E+01 |
| | Operation fatalities | | | | 1.0E–01 |
| | Operation injuries | | | | 5.8E+01 |

***Table D.3.4–29. Programwide Risks Associated With Treatment of RH-TRUW Under Regionalized Alternatives 2 and 3 and the Centralized Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 3.2 | | | |
| | Cancer fatalities | 1.6E–03 | | | |
| | Cancer incidence | 5.4E–03 | 3.7E–08 | | |
| | Genetic effects | 3.2E–04 | | | |
| Noninvolved worker MEI | Dose (rem) | 2.8E–03 | | | |
| | Cancer fatalities | 1.4E–06 | | | |
| | Cancer incidence | 4.8E–06 | 3.5E–11 | | |
| | Genetic effects | 2.8E–07 | | | |
| | Hazard index | | | 1.2E–08 | |
| Offsite population | Dose (person-rem) | 8.9E+01 | | | |
| | Cancer fatalities | 4.6E–02 | | | |
| | Cancer incidence | 1.6E–01 | 1.1E–07 | | |
| | Genetic effects | 8.9E–03 | | | |
| Offsite MEI | Dose (rem) | 2.8E–03 | | | |
| | Cancer fatalities | 1.4E–06 | | | |
| | Cancer incidence | 4.8E–06 | 5.7E–12 | | |
| | Genetic effects | 2.8E–07 | | | |
| | Hazard index | | | 1.9E–09 | |
| WM workers | Dose (FTE-rem) | 2.4E+02 | | | |
| | Cancer fatalities | 9.6E–02 | | | |
| | Cancer incidence | 3.4E–01 | 5.2E–06 | | |
| | Genetic effects | 1.4E–02 | | | |
| | Exposure index | | | 2.4E–05 | |
| | Construction fatalities | | | | 3.1E–01 |
| | Construction injuries | | | | 1.2E+02 |
| | Operation fatalities | | | | 1.5E–01 |
| | Operation injuries | | | | 9.4E+01 |

***Table D.3.4–30. Risks Associated With Treatment of RH-TRUW Under the No Action Alternative, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| ANL-E | 7,939,785 / 30 | 7.4E–08 | 4.1E–13 | 6.1E–03 | 2.5E–07 | 1.4E–12 | 1.0E–07 |
| Hanford | 377,645 / 442 | 2.7E–06 | 5.6E–11 | 1.0E–01 | 9.1E–06 | 1.9E–10 | 2.2E–01 |
| INEL | 153,061 / 77 | 4.1E–09 | 5.1E–13 | 1.6E–02 | 1.4E–08 | 1.7E–12 | 1.0E–05 |
| LANL | 159,152 / 5 | 6.7E–10 | 7.0E–14 | 1.1E–03 | 2.3E–09 | 2.4E–13 | 3.5E–09 |
| ORR | 881,652 / 41 | 6.6E–08 | 2.1E–12 | 8.4E–03 | 2.3E–07 | 7.4E–12 | 1.3E–06 |
| SRS | 620,618 / 4 | 5.1E–09 | 4.8E–14 | 3.2E–04 | 1.7E–08 | 1.6E–13 | 5.5E–06 |
| Total | | 2.8E–06 | 5.6E–11 | 1.3E–01 | 9.6E–06 | 1.9E–10 | 2.2E–01 |

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.4–31. Risks Associated With Treatment of RH-TRUW Under the Decentralized Alternative, by Site***

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| ANL-E | 7,939,785 / 62 | 1.9E–07 | 1.1E–12 | 2.6E–02 | 6.5E–07 | 3.6E–12 | 5.8E–04 |
| Hanford | 377,645 / 552 | 6.4E–06 | 1.3E–10 | 1.0E–01 | 2.2E–05 | 4.5E–10 | 6.8E–04 |
| INEL | 153,061 / 168 | 1.2E–08 | 1.6E–12 | 5.9E–02 | 4.2E–08 | 5.3E–12 | 3.7E–03 |
| LANL | 159,152 / 51 | 2.0E–08 | 2.1E–12 | 2.3E–02 | 6.7E–08 | 7.1E–12 | 4.8E–04 |
| ORR | 881,652 / 270 | 8.0E–07 | 2.5E–11 | 9.3E–02 | 2.9E–06 | 9.2E–11 | 9.5E–03 |
| SRS | 620,618 / 6 | 1.3E–08 | 1.2E–13 | 5.8E–03 | 4.4E–08 | 4.1E–13 | 2.8E–07 |
| Total | | 7.4E–06 | 1.3E–10 | 3.1E–01 | 2.6E–05 | 4.5E–10 | 1.5E–02 |

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with radiation exposure and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

*Table D.3.4–32. Risks Associated With Treatment of RH-TRUW Under Regionalized Alternative 1, by Site*

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| ANL-E | 7,939,785 / 29 | 2.0E–07 | 1.1E–12 | 8.9E–03 | 6.9E–07 | 3.8E–12 | 5.2E–04 |
| Hanford | 377,645 / 982 | 1.2E–05 | 2.4E–10 | 1.7E–01 | 4.0E–05 | 8.3E–10 | 7.5E–03 |
| INEL | 153,061 / 105 | 1.6E–08 | 2.0E–12 | 3.3E–02 | 5.4E–08 | 6.7E–12 | 3.5E–03 |
| LANL | 159,152 / 35 | 2.5E–08 | 2.6E–12 | 1.1E–02 | 8.5E–08 | 9.0E–12 | 4.6E–04 |
| ORR | 881,652 / 314 | 8.3E–07 | 2.6E–11 | 1.1E–01 | 3.0E–06 | 9.5E–11 | 9.7E–03 |
| SRS | 620,618 / 4 | 5.7E–09 | 5.4E–14 | 6.9E–04 | 1.9E–08 | 1.8E–13 | 9.9E–06 |
| Total | | 1.3E–05 | 2.4E–10 | 3.3E–01 | 4.4E–05 | 8.3E–10 | 2.2E–02 |

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with radiation exposure and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

*Table D.3.4–33. Risks Associated With Treatment of RH-TRUW Under Regionalized Alternatives 2 and 3 and the Centralized Alternative, by Site*

| Site | Population[a] | Fatalities[b] | | | Cancer Incidence[c] | | |
|---|---|---|---|---|---|---|---|
| | | Offsite Population | Offsite MEI | Workers | Offsite Population | Offsite MEI | Workers |
| LANL | 159,152 / 35 | 2.5E–08 | 2.6E–12 | 1.1E–02 | 8.5E–08 | 9.0E–12 | 4.6E–04 |
| ORR | 881,652 / 682 | 4.6E–02 | 1.4E–06 | 3.0E–01 | 1.6E–01 | 4.8E–06 | 3.2E–01 |
| ANL-E | 7,939,785 / 29 | 2.0E–07 | 1.1E–12 | 8.9E–03 | 6.9E–07 | 3.8E–12 | 5.2E–04 |
| Hanford | 377,645 / 1,471 | 6.4E–04 | 1.3E–08 | 2.1E–01 | 2.2E–03 | 4.5E–08 | 1.4E–02 |
| INEL | 153,061 / 105 | 1.6E–08 | 2.0E–12 | 3.3E–02 | 5.4E–08 | 6.7E–12 | 3.5E–03 |
| SRS | 620,618 / 4 | 5.7E–09 | 5.4E–14 | 6.9E–04 | 1.9E–08 | 1.8E–13 | 9.9E–06 |
| Total | | 4.7E–02 | 1.4E–06 | 5.6E–01 | 1.6E–01 | 4.8E–06 | 3.4E–01 |

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with radiation exposure and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

***Table D.3.4–34. RH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population at Each Site, by Alternative***

| Alternative | Site | | | | | |
|---|---|---|---|---|---|---|
| | ANL-E | Hanford | INEL | LANL | ORR | SRS |
| No Action | Pu-239[a]<br>3.13E–08[b] | Pu-239<br>9.0E–07 | Pu-241<br>2.13E–09 | Pu-239<br>3.53E–10 | Cm-244<br>3.22E–08 | Pu-238<br>3.0E–09 |
| Decentralized | Pu-239<br>8.02E–08 | Pu-239<br>2.1E–06 | Pu-241<br>6.64E–09 | Pu-239<br>1.04E–08 | Cm-244<br>3.75E–07 | Pu-238<br>8.0E–09 |
| Regionalized 1 | Pu-239<br>8.53E–08 | Pu-239<br>3.9E–06 | Pu-241<br>8.46E–09 | Pu-239<br>1.31E–08 | Cm-244<br>3.75E–07 | Pu-238<br>3.0E–09 |
| Regionalized 2, 3, and Centralized | Pu-239<br>8.53E–08 | Pu-239<br>4.3E–04 | Pu-241<br>8.46E–09 | Pu-239<br>1.31E–08 | Cm-244<br>2.11E–02 | Pu-238<br>3.0E–09 |

[a] Radionuclide contributing most risk of cancer fatality.
[b] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this site.

### D.3.4.7 Results of the RH-TRUW Human Health Risk Analysis

#### D.3.4.7.1 *Programwide Trends in Human Health Risks Associated With RH-TRUW Management Alternatives*

In general, the overall risks associated with managing RH-TRUW are somewhat lower than the risks from managing CH-TRUW. No Action presents the lowest health risks for all public and noninvolved worker populations and for all health risk endpoints because there is no waste treatment other than packaging. For the offsite, noninvolved worker, and worker populations, the health risks associated with the remaining RH-TRUW alternatives generally increase as more extensive waste treatment is employed; the highest estimated health risks are for the RH-TRUW scenario associated with the Regionalized 2, 3, and Centralized Alternatives, which involves incinerating RH-TRUW to destroy organic chemicals to meet RCRA LDRs. For workers, health risks are similar among the alternatives that include waste treatment. Overall, the health risks from exposure to chemicals in RH-TRUW are lower than from exposure to radionuclides, and the probability of adverse effects from noncarcinogenic, hazardous chemicals is very low. Estimated impacts to each receptor population are summarized below.

**Offsite Population**. Radiological and chemical exposure risks to the offsite population are lowest for No Action in which RH-TRUW is stored, without treatment, at the six generator sites in existing or approved facilities. The programwide risk of cancer fatality for this alternative is 2.8E–06 distributed over a total affected offsite population of approximately 10 million (see Tables D.3.4–23 and D.3.4–24).

The exposure risks to offsite populations in Decentralized (in which wastes are treated to WIPP waste acceptance criteria and stored at six sites) and Regionalized 1 (in which wastes are treated to reduce gas generation and stored at two sites) are slightly higher than those for No Action and are distributed over a similar total population. Treatment of RH-TRUW to LDRs and storage at two sites (Regionalized 2, 3, and Centralized Alternatives) results in markedly higher risks to offsite populations than in the other alternatives, with 4.6E–02 estimated cancer fatalities over a total population of approximately 10 million people.

Table D.3.4–33 shows that the predominant portion of the estimated cancer risks when RH-TRUW is treated to meet LDRs and stored at Hanford and ORR (Regionalized 2, 3, and Centralized Alternatives) is

attributed to ORR, where 4.6E–02 cancer fatalities in a population of 881,652 are estimated to occur over the 10-year treatment period. The higher estimated cancer risks at this site are linked to its relatively large inventory of curium-244 (the larger the contaminant inventory with respect to other sites, the larger the amount of contaminant assumed to be released during treatment).

Estimated programwide risks of cancer incidence from exposure to carcinogenic chemicals remain fairly consistent across alternatives, in the E–07 order of magnitude in all alternatives except No Action, in which cancer incidence risk is 8.1E–09 for the offsite population.

**Noninvolved Worker Population**. The programwide health risks to noninvolved worker populations parallel the trends observed for offsite populations but are slightly lower and involve a smaller affected population of 38,057 (see Table D.3.4–24). Treatment of RH-TRUW to LDRs and storage at two sites (Regionalized 2, 3, and Centralized Alternatives) poses the highest programwide risk to noninvolved worker populations (1.6E–03 total estimated cancer fatalities). The risk of cancer incidence due to exposure to carcinogenic chemicals is in the E–08 order of magnitude in all except No Action, where it is lower by approximately 1 order of magnitude (see Tables D.3.4–26 through D.3.4–29).

**Maximally Exposed Noninvolved Worker and Maximally Exposed Offsite Individual**. As shown in Table D.3.4–25, radiological risks to the noninvolved worker and offsite MEIs are lowest in No Action, slightly higher in Decentralized and Regionalized 1, and highest by approximately 4 orders of magnitude in the other alternatives (where RH-TRUW is treated to LDRs and stored at ORR and Hanford). Risks from chemical exposure follow a similar pattern. These trends generally parallel that seen for the total noninvolved worker and offsite populations.

Tables D.3.4–30 through D.3.4–33 show that the highest risks of cancer fatality to the offsite MEI are at Hanford and ORR in the Regionalized 2, 3, and Centralized Alternatives. These elevated risks are due to increased exposure from emissions during treatment to LDRs.

On the program level, estimated risk of cancer incidence due to chemical exposure is similar among alternatives and does not exceed the E–11 order of magnitude. While both MEI hazard indices are 2–3 orders of magnitude higher in Regionalized 2, 3, and Centralized than in No Action, the hazard indices in all alternatives are well below 1.0, indicating a low probability of adverse health effects from noncarcinogenic, hazardous constituents.

**Workers**. All exposures to FTEs are below regulatory limits. As was the case for CH-TRUW, RH-TRUW worker exposure and physical hazard risks generally increase as treatment increases in extent. Estimated construction and operational fatalities are always higher than those associated with radiation exposure, regardless of alternative. No Action results in lower worker health risks from physical hazards because fewer person-hours are spent in construction and operation of facilities, therefore injuries and fatalities are less likely. The risks from physical hazards are highest for the alternatives involving treatment (all except No Action) and are similar among these alternatives. Programwide radiological risks to workers are among the lowest in No Action (6.2E–02 estimated cancer fatalities over a population of 59 FTEs), slightly lower in Decentralized and Regionalized 1 (4.3E–03 and 6.2E–03, respectively), and increase somewhat in the other alternatives.

Worker health risks associated with chemical exposure vary slightly among alternatives. The exposure index, or highest individual worker exposure to noncarcinogenic chemicals, is approximately 1 order of magnitude lower in No Action than for the alternatives that involve treatment. However, in all alternatives the exposure indices are well below 1.0, indicating a low probability of adverse health effects from noncarcinogenic, hazardous constituents. The risk of worker cancer incidence from chemical exposure rises gradually across alternatives (lowest in No Action and slightly higher in the Decentralized, Regionalized, and Centralized Alternatives). Chemical exposure contributes much less to worker health risk estimates than radiation exposure.

**Discussion**. As stated above, radiation exposure risks are greater than chemical exposure risks for RH-TRUW for all populations by several orders of magnitude. The risks of worker fatalities due to physical hazards are always greater than those due to exposure.

For the offsite population, Hanford poses the highest estimated cancer fatalities in all alternatives except Regionalized 2, 3, and Centralized, where the highest risk is at ORR. The radionuclides contributing the most risk to the offsite population are plutonium-239 at Hanford in No Action, Decentralized, and Regionalized 1–3, and Centralized; and curium-244 at ORR in Regionalized 2, 3, and Centralized (see Table D.3.4–34).

For workers, the highest estimated total fatalities (cancer fatalities plus construction and operational fatalities) in all alternatives are associated with Hanford, where the most FTEs are involved in RH-TRUW management. Total fatality risks (as well as numbers of FTEs) are second highest at INEL in No Action, and at ORR in all other alternatives. In No Action, the radionuclides contributing the most worker risk are plutonium-241 at INEL, through inhalation; and plutonium-238 at Hanford, through inhalation. The controlling radionuclides for worker risks in Decentralized are uranium-236 at Hanford, through inhalation; and europium-152 and its radioactive decay products at ORR, through external exposure. In Regionalized 1 at Hanford, and in Regionalized 2, 3, and Centralized at ORR and Hanford, the controlling radionuclide is uranium-233, through inhalation.

#### D.3.4.7.2 *Comparison of the Decentralized and Regionalized 1 Alternatives: Treatment to WIPP Waste Acceptance Criteria Versus Treatment to Reduce Gas Generation*

A comparison of Decentralized (in which RH-TRUW is treated to WIPP waste acceptance criteria and stored at six installations) and Regionalized 1 (in which RH-TRUW is treated to reduce gas generation and stored at two installations) shows few differences in the health risks associated with these two treatment and consolidation options. The major difference between treating to WIPP waste acceptance criteria and treating to reduce gas generation is the addition of a waste shredding step in Regionalized 1, therefore, treatment risks should not be substantially different. The number of installations at which waste is consolidated also does not greatly affect the overall health risks.

#### D.3.4.7.3 *Comparison of Regionalized Alternative 1 With Regionalized Alternatives 2 and 3 and the Centralized Alternative: Treatment to Reduce Gas Generation Versus Treatment to Meet Land Disposal Restrictions*

A more controlled comparison of treatment risks can be made between the Regionalized 1 and the Regionalized 2 and 3, and Centralized Alternatives since consolidation schemes are identical (wastes are treated and stored at the same two installations in all of these alternatives) but treatments differ (treatment to reduce gas generation in Regionalized 1 versus treatment to LDRs in the other three alternatives). As previously noted, the programwide risks of cancer fatalities, cancer incidence, and genetic effects from radiation exposure associated with treatment of RH-TRUW to LDRs (in the Regionalized 2, 3, and Centralized Alternatives) are approximately 3 orders of magnitude greater for the offsite and noninvolved worker populations and MEIs than the risks from treatment to minimize gas generation in Regionalized 1.

The offsite and noninvolved worker MEI hazard indices associated with treatment of RH-TRUW to LDRs are approximately 1 order of magnitude higher than in Regionalized 1. This trend reflects the potential for higher individual exposure to noncarcinogenic hazardous chemicals when RH-TRUW undergoes treatment to meet LDRs rather than to reduce gas generation. However, in all alternatives, exposures to noncarcinogenic, hazardous chemicals yield hazard indices well below 1.0, indicating a very low probability of adverse effects from these contaminants.

The programwide risks to workers from radionuclide exposure are more than 1 order of magnitude higher in the alternatives involving treatment to LDRs than in Regionalized 1. However, the risk of chemical-related cancer incidence is similar between alternatives.

#### D.3.4.7.4 *Summary*

In summary, the No Action Alternative presents the fewest health risk to all populations. Health risks generally increase for the public receptors as more extensive treatment of RH-TRUW is employed. Radionuclide- and construction/operational-related health risks to workers increase somewhat as more extensive treatment is employed. Chemical-related risks for all receptors are slightly higher in the alternatives that involve treatment (all except No Action) than in No Action, but are relatively independent of treatment type.

The primary risk drivers for the offsite and noninvolved worker populations are radiation exposure (as opposed to chemical exposure) and treatment option. For workers, the primary risk drivers are the size of the waste load and the person-hours necessary to process it.

### D.3.4.8 Summary of Alternatives for Potential CH-TRUW Accidents

The following CH-TRUW alternatives were evaluated for potential treatment facility (incinerator) accidents: Regionalized 2, Regionalized 3, and Centralized. No storage accidents were analyzed. Health risks associated with accidental releases of radionuclides were analyzed, while health risks associated with accidental releases of chemicals were not analyzed. The types of accidents evaluated were (1) an incinerator explosion and resulting fire; (2) a baghouse area fire; and (3) an earthquake and resulting fire.

### D.3.4.9 Special Assumptions and Considerations Used in the CH-TRUW Accident Analysis

All accidental releases from incinerator facilities to the outside (i.e., to the offsite and noninvolved worker populations) are assumed to be at ground level with dispersion starting at a lower level rather than from a facility stack. In the incinerator explosion accident scenario, it is assumed that the efficiency of the facility's high-efficiency particulate air filtration system drops only to 99.9%. In the assessment of worker risks from incineration accidents, it is assumed that the air in the work area is not ventilated or filtered; the intra-facility source term for this accident is, therefore, 1,000 times higher than the atmospheric source term used to calculate risks to the offsite and noninvolved worker populations.

Incineration accidents are assumed to cause releases into the operating gallery where the workers are located. Half of the operating gallery (e.g., an area 32 m long × 6 m wide × 6 m high) is assumed to fill with contaminated air. Exposure duration is 1 min, the time necessary for workers to avoid any obstructions and leave the scene. During all accidents, one shift of waste management workers is assumed to be inside the incinerator facility. Shift size varies from 2 to 14 workers.

Each accident type has an associated estimated annual frequency of occurrence as determined by Argonne National Laboratory (see Section D.2.7.1). However, the probability of occurrence is not directly taken into account in the risk calculations. Risk estimates associated with each accident should be interpreted as the consequences if the accident occurred. Estimated annual frequencies vary by accident type, installation location, and contaminant type. For radionuclide-related accidents, the incinerator explosion is considered to be "anticipated" (greater than 1E-02 per year); the baghouse area fire is considered "unlikely" (1E-4 to 1E-02 per year); and the earthquake with subsequent fire is considered "very unlikely" (1E-06 to 1E-04 per year).

### D.3.4.10 Results Tables for the Risk Analysis of Potential CH-TRUW Accidents

Table D.3.4-35 presents a summary of the maximum reasonably foreseeable accident risks to the offsite and noninvolved worker populations, their respective MEIs, and waste management worker populations for treatment facility accidents, by installation and alternative. Table D.3.4-36 provides the sizes of the offsite, noninvolved worker, and worker populations at each installation. Tables D.3.4-37 through D.3.4-45 present more detailed results by health endpoint and installation.

***Table D.3.4–35. Radionuclide-Related Risks from Potential Maximum Reasonably Foreseeable CH-TRUW Treatment Facility Accidents, by Alternative and Site***

| | Offsite Population | | Offsite MEI | | Noninvolved Worker Population | | Noninvolved Worker MEI[a] | | Worker Population | |
|---|---|---|---|---|---|---|---|---|---|---|
| Site | CF[b] | CI[c] | CF | CI | CF | CI | CF | CI | CF | CI |
| Regionalized 2 | | | | | | | | | | |
| HS | 2.1E+00 | 7.0E+00 | 4.9E–05 | 1.7E–04 | 4.0E–01 | 1.4E+00 | 4.0E–03 | 1.4E–02 | 5.5E+00 | 1.9E+01 |
| INEL | 3.0E–01 | 1.0E+00 | 3.4E–05 | 1.2E–04 | 4.3E–01 | 1.5E+00 | 2.6E–04 | 8.7E–04 | 1.9E+01 | 6.7E+01 |
| LANL | 2.8E+00 | 9.6E+00 | 1.3E–03 | 4.5E–03 | 8.0E–01 | 2.7E+00 | 2.4E–03 | 8.1E–03 | 2.7E+01 | 9.4E+01 |
| RFP | 1.9E+00 | 6.3E+00 | 6.6E–05 | 2.2E–04 | 2.7E–01 | 9.3E–01 | 8.1E–04 | 2.8E–03 | 1.4E+00 | 4.8E+00 |
| SRS | 8.0E–03 | 2.7E–02 | 2.5E–07 | 8.4E–07 | 1.8E–03 | 6.1E–03 | 7.7E–06 | 2.6E–05 | 1.6E–02 | 5.6E–02 |
| Regionalized 3 | | | | | | | | | | |
| HS | 2.1E+00 | 7.0E+00 | 4.9E–05 | 1.7E–04 | 4.0E–01 | 1.4E+00 | 4.0E–03 | 1.4E–02 | 5.5E+00 | 1.9E+01 |
| INEL | 7.3E–01 | 2.5E+00 | 8.3E–05 | 2.8E–04 | 1.1E+00 | 3.7E+00 | 6.6E–04 | 2.2E–03 | 5.8E+01 | 2.0E+02 |
| SRS | 8.0E–03 | 2.7E–02 | 2.5E–07 | 8.4E–07 | 1.8E–03 | 6.1E–03 | 7.7E–06 | 2.6E–05 | 1.6E–02 | 5.6E–02 |
| Centralized | | | | | | | | | | |
| WIPP | 7.4E+00 | 2.5E+01 | 6.2E–02 | 2.1E–01 | 1.9E+00 | 6.3E+00 | 5.7E–02 | 2.0E–01 | 7.1E+01 | 2.5E+02 |

[a]MEI--most-exposed individual; each value represents the highest single risk (not the sum of all risks) to the MEI from among all accidents at an installation.
[b]CF--risk of cancer fatality associated with exposure to radionuclides.
[c]CI--risk of cancer incidence associated with exposure to radionuclides.

***Table D.3.4–36. Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Potential CH-TRUW Treatment Accidents, by Site***

| Site | Offsite Population | Noninvolved Worker Population | WM Worker Population | | |
|---|---|---|---|---|---|
| | | | Regionalized 2 | Regionalized 3 | Centralized |
| Hanford | 377,645 | 8,674 | 9 | 9 | |
| INEL | 153,106 | 8,451 | 11 | 13 | |
| LANL | 159,152 | 11,552 | 11 | | |
| RFP | 2,171,877 | 6,993 | 5 | | |
| SRS | 620,618 | 15,996 | 2 | 2 | |
| WIPP | 99,889 | 1060 | | | 14 |

***Table D.3.4–37. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at Hanford Under the Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Population[c] | MEI | Workers | Population[c] | MEI | Workers |
| Incineration, Earthquake (VU)[d] | 2.1E+00 | 4.9E-05 | 3.0E-01 | 7.0E+00 | 1.7E-04 | 1.1E+00 |
| Incineration, Baghouse Area Fire (U) | 8.0E-03 | 1.9E-07 | 1.2E-03 | 2.7E-02 | 6.5E-07 | 4.1E-03 |
| Incineration, Incinerator Explosion (A) | 3.8E-02 | 8.9E-07 | 5.5E+00 | 1.3E-01 | 3.0E-06 | 9.0E+00 |
| Maximum reasonably foreseeable accident | 2.1E+00 | 4.9E-05 | 5.5E+00 | 7.0E+00 | 1.7E-04 | 9.0E+00 |

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (> 1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (< 1E-06).

***Table D.3.4–38. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at INEL Under the Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Population[c] | MEI | Workers | Population[c] | MEI | Workers |
| Incineration, Earthquake (VU)[d] | 3.0E-01 | 3.4E-05 | 1.0E+00 | 1.0E+00 | 1.2E-04 | 3.7E+00 |
| Incineration, Baghouse Area Fire (U) | 1.2E-03 | 1.3E-07 | 4.1E-03 | 4.0E-03 | 4.6E-07 | 1.4E-02 |
| Incineration, Incinerator Explosion (A) | 5.5E-03 | 6.2E-07 | 1.1E+01 | 1.9E-02 | 2.1E-06 | 1.1E+01 |
| Maximum reasonably foreseeable accident | 3.0E-01 | 3.4E-05 | 1.1E+01 | 1.0E+00 | 1.2E-04 | 1.1E+01 |

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (> 1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (< 1E-06).

***Table D.3.4–39. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at LANL Under the Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Population[c] | MEI | Workers | Population[c] | MEI | Workers |
| Incineration, Earthquake (VU)[d] | 2.8E+00 | 1.3E–03 | 1.5E+00 | 9.6E+00 | 4.5E–03 | 5.1E+00 |
| Incineration, Baghouse Area Fire (U) | 1.1E–02 | 5.2E–06 | 5.8E–03 | 3.8E–02 | 1.8E–05 | 2.0E–02 |
| Incineration, Incinerator Explosion (A) | 5.2E–02 | 2.4E–05 | 1.1E+01 | 1.8E–01 | 8.3E–05 | 1.1E+01 |
| Maximum reasonably foreseeable accident | 2.8E+00 | 1.3E–03 | 1.1E+01 | 9.6E+00 | 4.5E–03 | 1.1E+01 |

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (<1E–06).

***Table D.3.4–40. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at RFETS Under the Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Population[c] | MEI | Workers | Population[c] | MEI | Workers |
| Incineration, Earthquake (VU)[d] | 1.9E+00 | 6.6E–05 | 7.5E–02 | 6.3E+00 | 2.2E–04 | 2.6E–01 |
| Incineration, Baghouse Area Fire (U) | 7.3E–03 | 2.6E–07 | 3.0E–04 | 2.5E–02 | 8.8E–07 | 1.0E–03 |
| Incineration, Incinerator Explosion (A) | 3.4E–02 | 1.2E–06 | 1.4E+00 | 1.2E–01 | 4.1E–06 | 4.8E+00 |
| Maximum reasonably foreseeable accident | 1.9E+00 | 6.6E–05 | 1.4E+00 | 6.3E+00 | 2.2E–04 | 4.8E+00 |

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (<1E–06).

***Table D.3.4–41. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at SRS Under the Regionalized Alternative 2, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Population[c] | MEI | Workers | Population[c] | MEI | Workers |
| Incineration, Earthquake (VU)[d] | 8.0E–03 | 2.5E–07 | 8.7E–04 | 2.7E–02 | 8.4E–07 | 3.1E–03 |
| Incineration, Baghouse Area Fire (U) | 3.2E–05 | 9.8E–10 | 3.4E–06 | 1.1E–04 | 3.3E–09 | 1.2E–05 |
| Incineration, Incinerator Explosion (A) | 1.5E–04 | 4.6E–09 | 1.6E–02 | 5.0E–04 | 1.6E–08 | 5.6E–02 |
| Maximum reasonably foreseeable accident | 8.0E–03 | 2.5E–07 | 1.6E–02 | 2.7E–02 | 8.4E–07 | 5.6E–02 |

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (<1E–06).

***Table D.3.4–42. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at Hanford Under the Regionalized Alternative 3, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Population[c] | MEI | Workers | Population[c] | MEI | Workers |
| Incineration, Earthquake (VU)[d] | 2.1E+00 | 4.9E–05 | 3.0E–01 | 7.0E+00 | 1.7E–04 | 1.1E+00 |
| Incineration, Baghouse Area Fire (U) | 8.1E–03 | 1.9E–07 | 1.2E–03 | 2.7E–02 | 6.5E–07 | 4.1E–03 |
| Incineration, Incinerator Explosion (A) | 3.8E–02 | 8.9E–07 | 5.5E+00 | 1.3E–01 | 3.0E–06 | 9.0E+00 |
| Maximum reasonably foreseeable accident | 2.1E+00 | 4.9E–05 | 5.5E+00 | 7.0E+00 | 1.7E–04 | 9.0E+00 |

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (<1E–06).

***Table D.3.4–43. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at INEL Under Regionalized Alternative 3, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Population[c] | MEI | Workers | Population[c] | MEI | Workers |
| Incineration, (VU)[d] Earthquake | 7.3E–01 | 8.3E–05 | 3.2E+00 | 2.5E+00 | 2.8E–04 | 1.1E+01 |
| Incineration, (U) Baghouse Area Fire | 2.9E–03 | 3.3E–07 | 1.2E–02 | 9.8E–03 | 1.1E–06 | 4.3E–02 |
| Incineration, (A) Incinerator Explosion | 1.3E–02 | 1.5E–06 | 1.3E+01 | 4.6E–02 | 5.2E–06 | 1.3E+01 |
| Maximum reasonably foreseeable accident | 7.3E–01 | 8.3E–05 | 1.3E+01 | 2.5E+00 | 2.8E–04 | 1.3E+01 |

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (<1E–06).

***Table D.3.4–44. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at SRS Under Regionalized Alternative 3, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Population[c] | MEI | Workers | Population[c] | MEI | Workers |
| Incineration, (VU)[d] Earthquake | 8.0E–03 | 2.5E–07 | 8.7E–04 | 2.7E–02 | 8.4E–07 | 3.1E–03 |
| Incineration, (U) Baghouse Area Fire | 3.2E–05 | 9.8E–10 | 3.4E–06 | 1.1E–04 | 3.3E–09 | 1.2E–05 |
| Incineration, (A) Incinerator Explosion | 1.5E–04 | 4.6E–09 | 1.6E–02 | 5.0E–04 | 1.6E–08 | 5.6E–02 |
| Maximum reasonably foreseeable accident | 8.0E–03 | 2.5E–07 | 1.6E–02 | 2.7E–02 | 8.4E–07 | 5.6E–02 |

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (<1E–06).

***Table D.3.4–45. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at WIPP Under the Centralized Alternative, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Population[c] | MEI | Workers | Population[c] | MEI | Workers |
| Incineration, Earthquake (VU)[d] | 7.4E+00 | 6.2E–02 | 3.9E+00 | 2.5E+01 | 2.1E–01 | 1.4E+01 |
| Incineration, Baghouse Area Fire (U) | 2.9E–02 | 2.5E–04 | 1.5E–02 | 9.8E–02 | 8.3E–04 | 5.3E–02 |
| Incineration, Incinerator Explosion (A) | 1.4E–01 | 1.1E–03 | 1.4E+01 | 4.6E–01 | 3.9E–03 | 1.4E+01 |
| Maximum reasonably foreseeable accident | 7.4E+00 | 6.2E–02 | 1.4E+01 | 2.5E+01 | 2.1E–01 | 1.4E+01 |

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (> 1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (< 1E–06).

### D.3.4.11 Summary of the CH-TRUW Accident Analysis Results

For radionuclide-related incineration accidents in all alternatives, the dominant accident type for all receptors except the waste management worker is the earthquake with subsequent fire. For waste management workers, the dominant accident type is the incineration explosion.The highest installation-specific cancer fatality risks are associated with LANL and Hanford for all receptors in Regionalized 2 and Regionalized 3. For Centralized alternative, the highest installation-specific cancer fatality risks are associated with WIPP. Cancer fatality risks associated with operational incineration accidents such as the incineration explosion and baghouse area fire in alpha facilities are generally lower than those associated with similar accidents caused by an earthquake by 1 to 3 orders of magnitude for all receptors except waste management workers in all alternatives. Note that for workers, the risk of death from latent cancers due to exposure to radioactive materials released in such accidents may be smaller than the risk of fatality due to nonradiological impacts.

#### D.3.4.11.1 *Risks to the Offsite Population from CH-TRUW Accidents*

For incineration accidents involving releases of radionuclides due to an earthquake, cancer fatality risks to the offsite population range from 8.0E-03 to 7.4 in population sizes ranging from 99,889 to 620,618. Cancer fatality risks from operational accidents range from 3.2E-05 to 1.4E-01 in population sizes ranging from 99,889 to 620,618. Incineration accident risks at a given installation do not differ greatly among alternatives. Risks associated with a particular accident either remain the same at an installation across alternatives or increase only slightly with waste consolidation.

The incineration accident type resulting in the highest risks to offsite populations is the earthquake with subsequent fire. In each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and baghouse area fire) are approximately 2 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given installation. However, the estimated annual frequency of the earthquake scenario affecting the incinerator facility is "very unlikely" (1E-06 to 1E-04 per year) for all installations and alternatives, while the baghouse area fire and incinerator explosion are considered "unlikely" (1E-04 to 1E-02 per year) and "anticipated" (greater than 1E-02 per year), respectively.

LANL and Hanford have the highest cancer fatality risks to the offsite population from contact-handled alpha facility incineration accidents in Regionalized 2 because of relatively high releases of plutonium-238. For Regionalized 3, Hanford again has the highest cancer fatality risks, while WIPP is the highest cancer risk installation for Centralized. The highest cancer fatality risk at WIPP is 7.4 (distributed over a population of 99,889) for the earthquake scenario in the Centralized Alternative. LANL and Hanford have the next highest cancer fatality risks to the offsite population from incineration accidents caused by an earthquake (2.8 distributed over a population of 159,152 and 2.1 distributed over a population of 377,645, respectively). The controlling contaminant at WIPP, LANL, and Hanford is plutonium-238. Internal exposure is the primary route for all three installations. For the incinerator explosion accident, cancer fatality risks are again highest at LANL for Regionalized 2, at Hanford for Regionalized 3, and at WIPP for the Centralized Alternative. The controlling contaminant at all three installations is plutonium-238; the primary exposure route is internal. The risks for radionuclide-related cancer incidence and genetic effects follow the same general trend as for cancer fatalities.

#### D.3.4.11.2 *Risks to the Noninvolved Worker Population from CH-TRUW Accidents*

For radionuclide-related accidents, the trends in risk to the noninvolved worker population follow the trends for the offsite population, but vary slightly. For incineration accidents involving releases of radionuclides due to an earthquake, cancer fatality risks range from 1.8E-03 to 1.9 in population sizes ranging from 1,060 to 15,996. Cancer fatality risks from operational accidents range from 7.0E-06 to 3.4E-02 in population sizes ranging from 1,060 to 15,996. Incineration accident risks at a given installation do not differ greatly among alternatives. Risks associated with a particular accident either remain the same at an installation across alternatives or increase only slightly with waste consolidation.

The incineration accident type resulting in the highest risks to noninvolved worker populations is the earthquake with subsequent fire. For each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and baghouse area fire) are generally 2 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given installation. Recall, however, that the estimated annual frequency of the earthquake scenario affecting the incinerator facility is the lowest of the three accident types.

For the facility earthquake scenario, LANL produces the greatest risk of cancer fatalities in Regionalized 2, INEL produces the greatest risk of cancer fatalities in Regionalized 3, while WIPP is the highest-risk installation in the Centralized alternative. The maximum reasonably foreseeable accident risks occur at WIPP (1.9 cancer fatalities over a population of 1060), followed by INEL (1.1 cancer fatalities over a population of 8451) and LANL (0.8 cancer fatalities over a population of 11,552). The controlling contaminant at LANL and WIPP is plutonium-238. At INEL both americium-241 and plutonium-238 are the controlling radionuclides. For operational accidents, the highest-risk installations are LANL in Regionalized 2, INEL in Regionalized 3, and WIPP in the Centralized alternative. In these alternatives, cancer fatality risk associated with the worst-case incinerator accident (incinerator explosion) is 1.5E-02 for LANL in a population of 11,552, 2.0E-02 for INEL in a population of 8,451, and 3.4E-02 for WIPP in a population of 1060 . The controlling contaminants at INEL are americium-241 and plutonium-238. At both LANL and WIPP plutonium-238 is the controlling radionuclide.

### D.3.4.11.3 *Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual from CH-TRUW Accidents*

For radionuclide-related accidents, the trends in risk to the offsite MEI and noninvolved worker MEI generally follow those for their respective populations. Incineration accident risks at a given installation do not differ greatly among alternatives. Risks to the MEIs associated with a particular accident either remain the same at an installation across alternatives or increase only slightly with waste consolidation. Differences in cancer risks between earthquake accidents and internally-initiated accidents parallel those estimated for the offsite and noninvolved worker populations.

The highest-risk incineration accident type for both MEIs is the earthquake with subsequent fire by approximately two order of magnitude. The highest-risk installations for the offsite MEI differ somewhat from those observed for the offsite population. The highest installation-specific cancer fatality risk to the offsite MEI is from the earthquake scenario at LANL (1.3E-03) in Regionalized 2, INEL (8.3E-05) in Regionalized 3, and WIPP (6.2E-02) in the Centralized alternative. The next highest installation risks for the same earthquake scenario are at RFETS in Regionalized 2 (6.6E-05) and Hanford in Regionalized 3 (4.9E-05). In each alternative, the risks of cancer fatalities to the offsite MEI for other incinerator accidents are approximately 1 to 3 orders of magnitude lower than those for the earthquake scenario. For the

incinerator explosion accident, cancer risks to the offsite MEI are greatest at LANL (2.4E-05) in Regionalized 2, INEL (1.5E-06) in Regionalized 3, and WIPP (1.1E-03) in the Centralized Alternative.

The highest installation-specific cancer fatality risk to the noninvolved worker MEI is from the earthquake scenario at Hanford in Regionalized 2 and 3, and at WIPP in Centralized (ranging from 4.0E-03 to 5.7E-02). The next highest risk to the noninvolved worker MEI is from the same earthquake scenario at LANL in Regionalized 2 and INEL in Regionalized 3 (2.4E-03 and 6.6E-04 cancer fatalities, respectively). For the maximum reasonably foreseeable operational accident (incinerator explosion) the highest-risk installation for the noninvolved worker MEI is Hanford in Regionalized 2 and 3, and at WIPP in Centralized (ranging from 7.3E-05 to 1.1E-03).

#### D.3.4.11.4 *Risks to Waste Management Workers from CH-TRUW Accidents*

For incineration accidents involving releases of radionuclides, installation-specific worker risks are similar among alternatives, increasing only very slightly at installations where CH-TRUW is consolidated for treatment. Unlike all other receptors, the highest cancer-fatality risks to the waste management worker occur during the incinerator explosion accident. Estimated worker cancer fatalities associated with the incinerator explosion accident range from 1.6E-02 to 1.4E+01. For the earthquake accident, estimated worker cancer fatalities range from 8.7E-04 to 3.9. Shift size varies from 2 to 14 workers. In all alternatives, the incinerator explosion scenario produces the higher worker risks by about 1 to 2 orders of magnitude over the earthquake scenario and about 3 to 4 orders of magnitude over the baghouse area fire scenario.

The highest installation-specific cancer fatality risks associated with the incinerator accidents are for the incinerator explosion accident at LANL in Regionalized 2 (1.1E+01), at INEL in Regionalized 3 (1.3E+01), and at WIPP in Centralized (1.4E+01). For the earthquake facility incinerator accident, the highest installation cancer fatality risks are at LANL (1.5) in Regionalized 2, at INEL (3.2) in Regionalized 3, and WIPP in Centralized (3.9).

### D.3.4.12 Summary of Alternatives for Potential RH-TRUW Accidents

The following RH-TRUW alternatives were evaluated for potential treatment facility (incinerator) accidents: Regionalized 2, Regionalized 3, and Centralized. All three of these alternatives treat to RCRA LDRs and store at 2 installations. Thus all accident scenarios remain the same across alternatives. No storage accidents were analyzed for RH-TRUW. Health risks associated with accidental releases of radionuclides were analyzed, while health risks associated with accidental releases of chemicals were not analyzed. The types of treatment facility accidents evaluated were (1) an incinerator explosion and resulting fire; (2) a baghouse area fire; and (3) an earthquake with subsequent fire.

### D.3.4.13 Results Tables for the Risk Analysis of Potential RH-TRUW Accidents

Table D.3.4-46 presents a summary of the maximum reasonably foreseeable accident risks to the offsite and noninvolved worker populations, their respective MEIs, and waste management worker populations for treatment facility accidents, by installation and alternative. Table D.3.4-47 provides the sizes of the offsite, noninvolved worker, and worker populations at each installation. Tables D.3.4-48 through D.3.4-49 present more detailed results by health endpoint and installation.

***Table D.3.4–46. Radionuclide-Related Risks from Potential Maximum Reasonably Foreseeable RH-TRUW Treatment Facility Accidents, by Alternative and Site***

| Site | Offsite Population | | Offsite MEI | | Noninvolved Worker Population | | Noninvolved Worker MEI[a] | | Worker Population | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CF[b] | CI[c] | CF | CI | CF | CI | CF | CI | CF | CI |
| **Regionalized 2, 3, and Centralized** | | | | | | | | | | |
| HS | 9.7E–03 | 3.3E–02 | 2.3E–07 | 7.7E–07 | 1.5E–03 | 4.9E–03 | 1.5E–05 | 4.9E–05 | 2.2E–03 | 7.8E–03 |
| ORNL | 1.2E–01 | 4.1E–01 | 1.0E–05 | 3.5E–05 | 4.6E–02 | 1.6E–01 | 5.1E–05 | 1.8E–04 | 8.9E–02 | 3.1E–01 |

[a] MEI=most-exposed individual; each value represents the highest single risk (not the sum of all risks) to the MEI from among all accidents at an installation.
[b] CF=risk of cancer fatality associated with exposure to radionuclides.
[c] CI=risk of cancer incidence associated with exposure to radionuclides.

***Table D.3.4–47. Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Potential RH-TRUW Treatment Accidents, by Site***

| Site | Offsite Population | Noninvolved Worker Population | WM Worker Population | | |
|---|---|---|---|---|---|
| | | | Regionalized 2 | Regionalized 3 | Centralized |
| Hanford | 377,645 | 8,674 | 1 | 1 | 1 |
| ORR | 881,652 | 3,809 | 7 | 7 | 7 |

***Table D.3.4–48. Radionuclide-Related Accident Risks Associated With RH-TRUW Treatment at Hanford Under the Regionalized Alternative 2, 3, and Centralized Alternatives, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Population[c] | MEI | Workers | Population[c] | MEI | Workers |
| Incineration, Earthquake (VU)[d] | 9.7E–03 | 2.3E–07 | 1.2E–04 | 3.3E–02 | 7.7E–07 | 4.3E–04 |
| Remote Incineration, Baghouse Area Fire (U) | 3.8E–05 | 8.9E–10 | 4.8E–07 | 1.3E–04 | 3.0E–09 | 1.7E–06 |
| Remote Incineration, Incinerator Explosion (A) | 1.8E–04 | 4.2E–09 | 2.2E–03 | 6.1E–04 | 1.4E–08 | 7.8E–03 |
| Maximum reasonably foreseeable accident | 9.7E–03 | 2.3E–07 | 2.2E–03 | 3.3E–02 | 7.7E–07 | 7.8E–03 |

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (> 1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (< 1E–06).

***Table D.3.4–49. Radionuclide-Related Accident Risks Associated With RH-TRUW Treatment at ORNL Under the Regionalized Alternative 2, 3, and Centralized Alternatives, by Accident Type***

| Accident | Cancer Fatalities[a] | | | Cancer Incidence[b] | | |
|---|---|---|---|---|---|---|
| | Population[c] | MEI | Workers | Population[c] | MEI | Workers |
| Incineration, Earthquake (VU)[d] | 1.2E–01 | 1.0E–05 | 4.8E–03 | 4.1E–01 | 3.5E–05 | 1.7E–02 |
| Remote Incineration, Baghouse Area Fire (U) | 4.7E–04 | 4.0E–08 | 1.9E–05 | 1.6E–03 | 1.4E–07 | 6.6E–05 |
| Remote Incineration, Incinerator Explosion (A) | 2.2E–03 | 1.9E–07 | 8.9E–02 | 7.5E–03 | 6.4E–07 | 3.1E–01 |
| Maximum reasonably foreseeable accident | 1.2E–01 | 1.0E–05 | 8.9E–02 | 4.1E–01 | 3.5E–05 | 3.1E–01 |

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (> 1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (< 1E–06).

## D.3.4.14 Summary of the RH-TRUW Accident Analysis Results

In general, the overall risks associated with managing RH-TRUW are somewhat lower than the risks from managing CH-TRUW. For radionuclide-related incineration accidents in all alternatives, the dominant accident type for all receptors except the waste management worker is the earthquake and resulting fire. For waste management workers, the dominant accident type is the incineration explosion.The highest installation-specific cancer fatality risks are associated with ORR for all receptors in all alternatives (Regionalized 2, 3 and Centralized). Cancer fatality risks associated with incineration accidents in remote facilities are generally lower than those associated with similar accidents caused by an earthquake by 2 to 3 orders of magnitude for all receptors (except waste management workers) in all alternatives. Note that for workers, the risk of death from latent cancers due to exposure to radioactive materials released in such accidents may be smaller than the risk of fatality due to nonradiological impacts.

### D.3.4.14.1 *Risks to the Offsite Population from RH-TRUW Accidents*

For incineration accidents involving releases of radionuclides due to an earthquake, cancer fatality risks to the offsite population range from 9.7E-03 to 1.2E-01 in population sizes ranging from 377,645 to 881,652.

Cancer fatality risks from internally-initiated accidents range from 3.8E-05 to 2.2E-03 in population sizes ranging from 377,645 to 881,652. Incineration accident risks at a given site do not differ among alternatives. Risks associated with a particular accident remain the same at a site across all alternatives.

The incineration accident type resulting in the highest risks to offsite populations is the earthquake with subsequent fire. In each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and baghouse area fire) are approximately 1 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given site. However, the estimated annual frequency of the earthquake scenario affecting the incinerator facility is "very unlikely" (1E-06 to 1E-04 per year) for all sites and alternatives, while the baghouse fire and incinerator explosion are considered "unlikely" (1E-04 to 1E-02 per year) and "anticipated" (greater than 1E-02 per year), respectively.

ORR has the highest cancer fatality risks to the offsite population from remote-handled alpha facility incineration accidents in all alternatives (Regionalized 2, Regionalized 3, and Centralized) because of relatively high releases of curium-244. Cancer fatalities of 2.2E-03 over a population of 881,652 are estimated to occur at ORR for the incinerator explosion. For the earthquake scenario, ORR once again has the highest cancer fatality risks with 1.2E-01 over a population of 881,652. Hanford is always the second highest cancer fatality site in all three alternatives by one to two orders of magnitude.The controlling contaminant at ORR is curium-244. Internal exposure is the primary route. The controlling contaminant at Hanford is plutonium-239; the primary exposure route is internal. The risks of radionuclide-related cancer incidence and genetic effects follow the same general trend as for cancer fatalities.

### D.3.4.14.2 *Risks to the Noninvolved Worker Population from RH-TRUW Accidents*

For radionuclide-related accidents, the trends in risk to the noninvolved worker population follow the trends for the offsite population. For incineration accidents involving releases of radionuclides due to an earthquake, cancer fatality risks range from 1.5E-03 to 4.6E-02 in population sizes ranging from 3,809 to 8,674. Cancer fatality risks from operational accidents range from 5.7E-06 to 8.5E-04 in population sizes ranging from 3,809 to 8,674. Incineration accident risks at a given installation do not differ among alternatives. Risks associated with a particular accident remain the same at a site across all alternatives.

The incineration accident type resulting in the highest risks to noninvolved worker populations is the earthquake with subsequent fire. For each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and baghouse area fire) are approximately 2 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given site. Recall, however, that the estimated annual frequency of the earthquake scenario affecting the incinerator facility is the lowest of the three accident types.

For the facility earthquake scenario, ORR produces the greatest risk of cancer fatalities in all alternatives (Regionalized 2, Regionalized 3, and Centralized). The worst-case accident risks occur during the facility earthquake scenario at ORR with 4.6E-02 cancer fatalities over a population of 3,809, followed by Hanford with 1.5E-03 cancer fatalities over a population of 8,674. For operational accidents, the highest-risk site is once again ORR for all alternatives, followed by Hanford. In these alternatives, cancer fatality risk associated with the worst-case incinerator accident (incinerator explosion) is 8.5E-04 for ORR in a population of 3,809, and 2.7E-05 for Hanford in a population of 8,674.

#### D.3.4.14.3 *Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual from RH-TRUW Accidents*

For radionuclide-related accidents, the trends in risk to the offsite MEI and noninvolved worker MEI generally follow those for their respective populations. Incineration accident risks at a given site do not differ among alternatives. Risks to the MEIs associated with a particular accident remain the same at an installation across all alternatives. Differences in cancer risks between earthquake facility incineration accidents and internally-initiated facility incineration accidents parallel those estimated for the offsite and noninvolved worker populations.

The highest-risk incineration accident type for both MEIs is the earthquake with subsequent fire. The highest site-specific cancer fatality risk to the offsite MEI is from the facility earthquake scenario at ORR for all alternatives (Regionalized 2, Regionalized 3, and Centralized). Estimated cancer fatality risks to the offsite MEI at ORR are 1.0E-05. The next highest site risks are for the same facility earthquake scenarios at Hanford for all alternatives (2.3E-07). For the operational accidents of which the incinerator explosion is the worst-case accident, cancer fatality risks to the offsite MEI are once again greatest at ORR (1.9E-07)

for all alternatives. Hanford has the next highest risk with 4.2E-09 estimated cancer fatalities for all alternatives.

The risks to the noninvolved worker MEI follows the same trends in risk as those to the offsite MEI. The earthquake scenario at ORR is the worst-case accident for the noninvolved worker MEI for all alternatives. Estimated cancer fatality risks to the noninvolved worker MEI at ORR is 5.1E-05. Hanford has the next highest risk with 1.5E-05 estimated cancer fatalities for the same type of accident. For the operational accidents of which the incinerator explosion is the worst-case accident, ORR is once again the highest site-specific cancer fatality risk with 9.4E-07 estimated cancer fatalities. Hanford has the next highest risk with 2.7E-07 estimated cancer fatalities for the incinerator explosion.

#### D.3.4.14.4 *Risks to Waste Management Workers from RH-TRUW Accidents*

For incineration accidents involving releases of radionuclides, site-specific worker risks are the same among alternatives. Unlike all other receptors, the highest cancer-fatality risks to the waste management worker occur during the incinerator explosion accident. Estimated worker cancer fatalities associated with the earthquake facility incineration accident range from 1.2E-04 to 4.8E-03. For operational accident scenarios, estimated worker cancer fatalities range from 4.8E-07 to 8.9E-02. Shift size varies from 1 to 7 workers. In all alternatives, the incinerator explosion scenario produces the higher worker risks by about 1 order of magnitude over the earthquake scenario and about 3 to 4 orders of magnitude over the baghouse area fire scenario.

The highest site-specific cancer fatality risks associated with the incinerator accidents are for the incinerator explosion at ORR with 8.9E-02 estimated cancer fatalities. Hanford has 2.2E-03 estimated cancer fatalities for this same type of accident. For the earthquake scenario accident, ORR once again has the highest site cancer fatality risks followed by Hanford (4.8E-03 and 2.3E-07, respectively).

### D.3.5 Low-Level Mixed Waste

Low-level mixed waste (LLMW) is waste that contains both low-level radioactivity and hazardous components regulated under the Resource Conservation and Recovery Act in sufficient quantities to render the waste hazardous per the guidelines of 40 CFR 261. Although asbestos-containing wastes are not considered hazardous under the Resource Conservation and Recovery Act, friable asbestos waste is considered a hazardous waste in several states. For the purposes of the PEIS, low-level radioactive waste contaminated with asbestos is considered LLMW. High-level waste, transuranic waste, or spent nuclear fuel that may be contaminated with hazardous components regulated by the Resource Conservation and Recovery Act are not classified as LLMW and are not evaluated for human health risks in this portion of the appendix (high-level waste is considered in Section D.3.1 and transuranic wastes containing hazardous constituents are addressed in Section D.3.4).

Like low-level waste, LLMW may contain a wide range of radionuclides at activities ranging from trace amounts to thousands of curies. Packaged LLMW with a surface dose rate of less than 200 mrem/h is categorized as contact-handled LLMW (CH-LLMW). Packaged LLMW with a surface dose rate greater than 200 mrem/h emits sufficient penetrating beta, gamma, or neutron radiation to require remote handling, and is classified as remote-handled LLMW (RH-LLMW). The handling category determines the level of protective shielding needed to store and process the waste safely. The distinction between CH-LLMW and RH-LLMW is maintained in the human health risk analyses for both routine operations and accidents. The risks associated with each category are estimated and discussed separately.

LLMW is also categorized according to its content of alpha-emitting radionuclides (e.g., alpha LLMW or nonalpha LLMW) and polychlorinated biphenyls (PCBs) (e.g., PCB LLMW or non-PCB LLMW).

About 50 sites within the DOE complex generate LLMW, including those listed below (note that the abbreviations given here are used in the tables in this appendix):

- Argonne National Laboratory–East (ANL–E), Argonne, Illinois
- Brookhaven National Laboratory (BNL), Brookhaven, New York
- Fernald Environmental Management Project (FEMP), Fernald, Ohio
- Hanford Site (Hanford), Richland, Washington
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Inhalation Toxicology Research Institute (ITRI), Albuquerque, New Mexico

- Kansas City Plant (KCP), Kansas City, Missouri
- Knolls Atomic Power Laboratory–Kesselring (KAPL–K), Schenectady, New York
- Lawrence Berkeley Laboratory (LBL), Berkeley, California
- Lawrence Livermore National Laboratory (LLNL), Livermore, California
- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Mound Plant (Mound), Miamisburg, Ohio
- Nevada Test Site (NTS), Las Vegas, Nevada
- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee
- Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky
- Pantex Plant (Pantex), Amarillo, Texas
- Portsmouth Gaseous Diffusion Plant (PORTS), Piketon, Ohio
- Rocky Flats Environmental Technology Site (RFETS), Golden, Colorado
- Sandia National Laboratories–New Mexico (SNL-NM), Albuquerque, New Mexico
- Savannah River Site (SRS), Aiken, South Carolina
- West Valley Demonstration Project (WVDP), West Valley, New York

This list includes the 16 major sites considered for LLMW management described in Section 1.6.1 and Chapter 6 of Volume I.

Treatment risks were also estimated separately later in this section in Tables D.3.5–15 through D.3.5–21 for several other sites in addition to the 16 major sites. These sites include KAPL-K, LBL, Mound, and KCP. Treatment risks at these sites are contained in the programwide risk tables presented in this section (Tables D.3.5–7 through D.3.5–14) and in the alternative summary risk tables presented in Section 6.4 of Volume I.

Depending on its chemical and physical properties, LLMW can be grouped into waste stream categories according to the type of treatment needed, such as aqueous wastes, organic liquids, inorganic or organic sludges, contaminated soil with or without debris, or special wastes.

Chapters 3 and 6 of the PEIS and the LLMW technical report (ANL, 1996e) provide more detailed information on this waste, including LLMW inventories at DOE sites, estimated release rates, treatment categories used in the PEIS, considerations regarding disposal, and the process for developing PEIS LLMW alternatives.

### D.3.5.1 Summary of LLMW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized, and Centralized) and the rationale for developing the various LLMW analysis alternatives are discussed rigorously in the main body of the PEIS. A broad range of Decentralized, Regionalized, and Centralized Alternatives are analyzed for this waste stream:

- The No Action Alternative: In this alternative, all sites treat CH-LLMW and RH-LLMW using existing capabilities and store the treated waste onsite (there is no disposal scenario for this alternative).
- The Decentralized Alternative: In this alternative, 49 sites treat CH-LLMW and 15 sites dispose of it.
- The Regionalized Alternatives: Regionalized 1 involves treatment of CH-LLMW at 11 sites and disposal at 12. In Regionalized 2 and 3, CH-LLMW is treated at seven sites and disposed of at six and one site(s), respectively. Regionalized 4 entails treating CH-LLMW at four sites and disposing of it at six.
- The Centralized Alternative: Hanford treats and disposes of CH-LLMW in this alternative.
- The RH-LLMW management scenario (for all alternatives except No Action): four sites treat this waste and dispose of it onsite.

This series of alternatives makes it possible to compare the relative risks of consolidating CH-LLMW and treating it at varying numbers of sites, and the risks associated with a broad range of disposal configurations.

Table D.3.5–1 depicts the overall treatment and storage schemes for the LLMW alternatives; detailed information on waste consolidation scenarios can be found in the LLMW technical report (ANL, 1996e). Note that for the purposes of this risk analysis, the waste load from the ITRI has been added to the waste load for SNL-NM.

### D.3.5.2 Special Assumptions and Considerations Used in the LLMW Risk Analysis

The following chemicals were used as representatives of generic classes of chemical contaminants in the risk evaluation for the offsite and noninvolved worker populations: 1,2-dichloroethane (to represent compounds containing two chlorine atoms), 1,1,1-trichloroethane (to represent compounds containing three chlorine atoms), carbon tetrachloride (to represent compounds containing four chlorine atoms),

## *Table D.3.5–1. PEIS Alternatives for LLMW*

| Alternative | Scenario | ANL-E | FEMP | Hanford | INEL | LANL | LLNL | NTS | ORR | Pantex | PGDP | PORTS | RFETS | SNL-NM | SRS | WVDP | BNL | LBL | Mound | KCP | KAPL-K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action (CH and RH) All installations treat using existing capabilities and store onsite | Treat at all | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T |
| | Store at all | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| Decentralized CH treatment | CH treatment at 49 | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T |
| | Dispose at 15 | D | D | D | D | D | D | D | D | D | D | D | D | D | D | | D | | | | |
| Regionalized 1 CH treatment | CH treatment at 11 | | T | T | T | T | T | | T | T | T | T | T | | T | | | | | | |
| | Dispose at 12 | | D | D | D | D | D | D | D | D | D | D | D | | D | | | | | | |
| Regionalized 2 CH treatment | CH treatment at 7 | | | T | T | T | | | T | | | T | T | | T | | | | | | |
| | Dispose at 6 | | | D | D | D | | D | D | | | | | | D | | | | | | |
| Regionalized 3 CH treatment | CH treatment at 7 | | | T | T | T | | | T | | | T | T | | T | | | | | | |
| | Dispose at 1 | | | | | | | D | | | | | | | | | | | | | |
| Regionalized 4 CH treatment | CH treatment at 4 | | | T | T | | | | T | | | | | | T | | | | | | |
| | Dispose at 6 | | | D | D | D | | D | D | | | | | | D | | | | | | |
| Centralized CH treatment | CH treatment at 1 | | | T | | | | | | | | | | | | | | | | | |
| | Dispose at 1 | | | D | | | | | | | | | | | | | | | | | |
| (All alternatives except No Action) RH treatment | RH treatment at 4 | | | T | T | | | | T | | | | | | T | | | | | | |
| | Dispose at 4 | | | D | D | | | | D | | | | | | D | | | | | | |

Notes: T = treatment site; S = storage site; D = disposal site.

1,2,2-trichloro-1,1,2-trifluoroethane (to represent chlorofluorocarbons), benzene (to represent water-insoluble organic compounds), and acetone (to represent water-soluble organic compounds). It was also assumed that any chromium in the source term was the inhalation carcinogen, chromium (VI) (100%), due to lack of better information. This is a conservative assumption, and health risks associated with chromium (VI) may be overestimated.

For all disposal scenarios, it is assumed that shallow land burial will be used at sites west of the Mississippi River and tumulus (above-ground vault) disposal will be used at eastern sites. The exceptions are RFETS, which disposes in tumulus vaults, and SRS, which disposes in below-ground vaults.

It is assumed that, except in the No Action Alternative, LLMW disposal capacity at each site will be expanded as required to meet disposal demands.

The waste containers for CH-LLMW are assumed to be 55-gal drums; RH-LLMW is assumed to be packaged in concrete casks with 6-in. walls.

For the purposes of estimating the human health risks associated with treatment and disposal of LLMW, no distinction is made between PCB-contaminated LLMW and non-PCB LLMW. If a site is postulated to possess PCB-LLMW, the source term for that mixed waste is combined with all the other LLMW source terms for that site.

### D.3.5.3 Results Tables for the LLMW Human Health Risk Analysis

This section contains the results tables for the LLMW human health risk analysis. A discussion of the results is presented in Section D.3.5.4. The risk numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.5–2 presents an overview, by alternative, of the *total*, programwide risks associated with treatment of LLMW. Included are the risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste treatment. This table provides the estimated *total number* of people in the three populations who will develop or die of

cancers caused by exposure to LLMW if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed during construction and operational activities. The results in this table are drawn from Tables D.3.5–7 through D.3.5–14 on the following pages.

- Table D.3.5–3 presents an overview, by alternative, of the programwide risks associated with disposal of LLMW. This table summarizes the risks of cancer fatalities and cancer incidence for the MEL of the hypothetical farm family; the likelihood of adverse health effects to the maximally exposed lifetime (MEL) from exposure to noncarcinogenic, hazardous chemicals; the total risks to members of all 143 lifetimes of the farm family; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste disposal. The results in this table are drawn from Tables D.3.5–23 through D.3.5–29.
- Table D.3.5–4 shows the sizes of the total affected populations for each alternative.
- Table D.3.5–5 summarizes the risks to the noninvolved worker and offsite MEIs for each LLMW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will die of or develop cancer from radionuclide and chemical exposure and indicators of the likelihood of adverse health effects to the MEIs from exposure to noncarcinogenic, hazardous chemicals. These results are drawn from Tables D.3.5–7 through D.3.5–14 and Tables D.3.5–23 through D.3.5–29.
- Table D.3.5–6 lists the radionuclides that contribute most of the risk of cancer fatality to the offsite population for LLMW treatment, by site and alternative.

The following tables are located on the following pages:

- Tables D.3.5–7 through D.3.5–14 provide more detailed information on the programwide health risks to all receptors from treatment of LLMW, by alternative and health endpoint.
- Tables D.3.5–15 through D.3.5–22 present summaries of the health risks for the offsite and worker populations, by alternative and site.
- Tables D.3.5–23 through D.3.5–29 provide more detailed information on the programwide health risks to the MEL of the hypothetical farm family of four, all 143 lifetimes of the farm family, and waste disposal workers, by alternative and health endpoint.
- Tables D.3.5–30 through D.3.5–36 present summaries of the health risks to the farm family and workers and an indication of which farm family lifetime is maximally exposed, by installation.

***Table D.3.5–2. Summary of Programwide Risks Associated With Treatment of LLMW: Risks to Total Populations, by Alternative***

| Alternative | Offsite Population | | Noninvolved Worker Population | | WM Workers | | |
|---|---|---|---|---|---|---|---|
| | CF | CI | CF | CI | CF | CI | C&OF |
| No Action | 2.8E–01 | 1.0 | 1.3E–02 | 4.4E–02 | 8.4E–01 | 2.9 | 1.7 |
| Decentralized | 1.7E–01 | 5.8E–01 | 2.4E–03 | 8.0E–03 | 5.2E–01 | 1.8 | 4.0 |
| Regionalized 1 | 1.6E–01 | 5.5E–01 | 2.4E–03 | 8.0E–03 | 5.6E–01 | 2.0 | 3.7 |
| Regionalized 2 | 1.8E–02 | 6.1E–02 | 3.6E–04 | 1.2E–03 | 5.7E–01 | 2.0 | 3.4 |
| Regionalized 3 | 1.8E–02 | 6.1E–02 | 3.6E–04 | 1.2E–03 | 5.7E–01 | 2.0 | 3.4 |
| Regionalized 4 | 1.8E–02 | 5.9E–02 | 3.6E–04 | 1.2E–03 | 6.2E–01 | 2.2 | 3.1 |
| Centralized | 2.5E–02 | 8.6E–02 | 3.3E–04 | 1.1E–03 | 6.3E–01 | 2.2 | 2.6 |
| RH-LLMW | 1.3E–03 | 4.5E–03 | 4.2E–05 | 1.4E–04 | 2.3E–02 | 8.1E–02 | 4.5E–01 |

Notes: CF = cancer fatality associated with radionuclide exposure; CI = cancer incidence associated with exposure to radionuclides and carcinogenic chemicals; C&OF = fatalities due to the physical hazards of constructing and operating waste management facilities.

***Table D.3.5–3. Summary of Programwide Risks Associated With Disposal of LLMW: Risks to Hypothetical Farm Family and Waste Management Workers, by Alternative***

| Alternative | MEL of Farm Family | | | | All (143) Lifetimes of Farm Family | | | WM Workers | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CF | Rad CI | Chem CI | HI | CF | Rad CI | Chem CI | CF | CI | C&OF |
| Decentralized | 1.5E–03 | 4.9E–03 | 9.8E–03 | 2.4 | 3.5E–02 | 1.2E–01 | 4.9E–01 | 5.5E–01 | 1.9 | 4.3E–01 |
| Regionalized 1 | 1.2E–03 | 4.1E–03 | 9.8E–03 | 3.0 | 2.4E–02 | 8.0E–02 | 5.0E–01 | 5.5E–01 | 1.9 | 4.6E–01 |
| Regionalized 2 | 1.4E–03 | 4.8E–03 | 1.3E–02 | 2.7 | 2.4E–02 | 8.0E–02 | 8.3E–01 | 5.2E–01 | 1.8 | 4.2E–01 |
| Regionalized 3 | 0.00 | 0.00 | 7.2E–04 | 8.1E–01 | 0.00 | 0.00 | 3.0E–02 | 3.9E–01 | 1.4 | 8.4E–02 |
| Regionalized 4 | 1.5E–03 | 5.1E–03 | 1.3E–02 | 2.7 | 2.5E–02 | 8.5E–02 | 8.2E–01 | 6.4E–01 | 2.2 | 4.1E–01 |
| Centralized | 1.9E–02 | 6.6E–02 | 9.5E–04 | 2.4 | 2.5E–01 | 8.6E–01 | 8.5E–03 | 3.6E–01 | 1.3 | 1.5E–01 |
| RH-LLMW | 8.5E–05 | 2.9E–04 | 1.4E–05 | 1.3E–02 | 1.3E–03 | 4.5E–03 | 5.8E–04 | 1.5E–03 | 5.2E–03 | 3.0E–02 |

Notes: CF = risk of cancer fatality associated with exposure to both radionuclides and carcinogenic chemicals; Rad CI = risk of cancer incidence associated with exposure to radionuclides; Chem CI = Risk of cancer incidence associated with exposure to chemical carcinogens; HI = hazard index; C&OF = estimated construction and operational fatalities from physical hazards.

***Table D.3.5–4. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of LLMW, by Alternative***

| Alternative | Offsite Population | Noninvolved Worker Population | WM Workers |
|---|---|---|---|
| No Action | 53,223,046 | 113,878 | 10,261 |
| Decentralized | 53,223,046 | 113,878 | 13,070 |
| Regionalized 1 | 53,223,046 | 113,878 | 12,867 |
| Regionalized 2 | 53,223,046 | 113,878 | 12,467 |
| Regionalized 3 | 53,223,046 | 113,878 | 12,467 |
| Regionalized 4 | 53,223,046 | 113,878 | 11,261 |
| Centralized | 53,223,046 | 113,878 | 8,672 |
| RH-LLMW | 2,032,976 | 36,930 | 1,119 |

***Table D.3.5–5. Summary of Programwide Risks Associated With Treatment of LLMW: Risks to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative***

| Alternative | Offsite MEI | | | | Noninvolved Worker MEI | | | |
|---|---|---|---|---|---|---|---|---|
| | CF | Rad CI | Chem CI | HI | CF | Rad CI | Chem CI | HI |
| No Action | 3.5E–06 | 1.2E–05 | 2.0E–08 | 2.3E–05 | 8.7E–06 | 3.0E–05 | 2.1E–07 | 4.5E–05 |
| Decentralized | 2.5E–06 | 8.5E–06 | 1.2E–09 | 1.4E–06 | 7.3E–07 | 2.5E–06 | 7.1E–09 | 8.8E–06 |
| Regionalized 1 | 2.6E–06 | 8.7E–06 | 1.0E–09 | 1.4E–06 | 7.4E–07 | 2.5E–06 | 6.2E–09 | 8.7E–06 |
| Regionalized 2 | 2.7E–07 | 9.2E–07 | 1.0E–09 | 1.4E–06 | 3.1E–07 | 1.0E–06 | 6.2E–09 | 8.8E–06 |
| Regionalized 3 | 2.7E–07 | 9.2E–07 | 1.0E–09 | 1.4E–06 | 3.1E–07 | 1.0E–06 | 6.2E–09 | 8.8E–06 |
| Regionalized 4 | 2.7E–07 | 9.3E–07 | 1.5E–09 | 2.0E–06 | 3.1E–07 | 1.1E–06 | 9.3E–09 | 1.3E–05 |
| Centralized | 5.2E–07 | 1.8E–06 | 4.1E–10 | 4.5E–07 | 5.8E–07 | 2.0E–06 | 1.4E–08 | 1.6E–05 |
| RH-LLMW | 3.4E–08 | 1.2E–07 | 2.9E–12 | 4.8E–09 | 2.3E–08 | 7.8E–08 | 1.8E–11 | 3.8E–08 |

Notes: MEI = maximally exposed individual; CF = risk of cancer fatality associated with exposure to radionuclides; Rad CI = risk of cancer incidence associated with exposure to radionuclides; Chem CI = risk of cancer incidence associated with exposure to chemical carcinogens; HI = hazard index.

## *Table D.3.5–6. Radionuclide Contributing the Highest Risk of Cancer Fatality to the Offsite Population for LLMW Treatment, by Alternative and Site*

| | Site | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alt. | ANL-E | Hanford | INEL | KAPL-K | KCP | LANL | LBL | LLNL | NTS | ORR | Pantex | PORTS | PGDP | RFETS | SNL/NM | SRS | WVDP | FEMP | BNL | Mound |
| No Action | U-238[a] 1.24E-04[b] | Pu-238 1.11E-02 | Pu-238 3.85E-04 | Co-60 4.87E-04 | Co-60 4.61E-06 | Pu-238 8.81E-05 | U-238 3.45E-05 | Pu-238 7.55E-04 | U-238 8.1E-06 | U-238 1.09E-01 | Pu-238 1.45E-06 | U-238 5.92E-05 | U-238 3.32E-03 | Pu-238 1.63E-02 | Pu-238 3.13E-05 | H-3 2.60E-03 | Pu-238 2.03E-04 | U-238 5.90E-04 | U-238 1.08E-04 | Pu-238 1.38E-05 |
| Dec. | U-238 7.1E-06 | Pu-238 9.84E-04 | H-3 3.50E-05 | H-3 1.98E-04 | H-3 2.30E-06 | H-3 5.86E-04 | H-3 1.02E-02 | H-3 1.54E-01 | U-238 1.1E-06 | U-238 4.86E-04 | H-3 3.41E-05 | U-238 2.49E-06 | U-238 1.10E-04 | Pu-238 4.09E-05 | H-3 1.30E-04 | H-3 1.68E-03 | Pu-238 1.08E-07 | U-238 2.39E-05 | U-238 5.32E-06 | H-3 1.26E-04 |
| Reg. 1 | H-3 5.3E-07 | Pu-238 9.03E-04 | H-3 3.50E-05 | Co-60 1.05E-07 | Co-60 9.90E-10 | H-3 6.02E-04 | U-238 7.74E-09 | H-3 1.57E-01 | H-3 5.2E-09 | U-238 4.19E-04 | H-3 3.41E-05 | H-3 3.03E-05 | U-238 1.10E-04 | Pu-238 4.08E-05 | Pu-238 7.30E-09 | H-3 1.68E-03 | H-3 1.06E-07 | U-238 3.30E-04 | U-238 2.43E-08 | Pu-238 3.22E-09 |
| Reg. 2 | H-3 5.3E-07 | H-3 1.20E-02 | H-3 6.10E-04 | Co-60 1.05E-07 | Co-60 9.90E-10 | H-3 8.52E-04 | U-238 7.74E-09 | Pu-238 1.76E-07 | H-3 5.2E-09 | U-238 6.56E-04 | H-3 2.34E-06 | H-3 3.15E-05 | U-238 7.48E-07 | Pu-238 4.09E-05 | Pu-238 7.30E-09 | H-3 1.68E-03 | H-3 1.06E-07 | U-238 1.33E-07 | U-238 2.43E-08 | Pu-238 3.22E-09 |
| Reg. 3 | H-3 5.3E-07 | H-3 1.20E-02 | H-3 6.10E-04 | Co-60 1.05E-07 | Co-60 9.90E-10 | H-3 8.52E-04 | U-238 7.74E-09 | Pu-238 1.76E-07 | H-3 5.2E-09 | U-238 6.56E-04 | H-3 2.34E-06 | H-3 3.15E-05 | U-238 7.48E-07 | Pu-238 4.09E-05 | Pu-238 7.30E-09 | H-3 1.68E-03 | H-3 1.06E-07 | U-238 1.33E-07 | U-238 2.43E-08 | Pu-238 3.22E-09 |
| Reg. 4 | H-3 5.3E-07 | H-3 1.20E-02 | H-3 6.51E-04 | Co-60 1.05E-07 | Co-60 9.90E-10 | H-3 3.79E-05 | U-238 7.74E-09 | Pu-238 1.76E-07 | H-3 5.2E-09 | U-238 8.04E-04 | H-3 2.34E-06 | U-238 1.65E-08 | U-238 7.48E-07 | Pu-238 8.15E-07 | Pu-238 7.30E-09 | H-3 1.68E-03 | H-3 1.06E-07 | U-238 1.33E-07 | U-238 2.43E-08 | Pu-238 3.24E-09 |
| Cen. | H-3 5.3E-07 | H-3 2.30E-02 | H-3 4.83E-06 | Co-60 1.05E-07 | Co-60 9.90E-10 | H-3 3.79E-05 | U-238 7.74E-09 | Pu-238 1.76E-07 | H-3 5.2E-09 | U-238 2.18E-06 | H-3 2.34E-06 | U-238 1.65E-08 | U-238 7.48E-07 | Pu-238 8.15E-07 | Pu-238 7.30E-09 | H-3 9.81E-07 | H-3 1.06E-07 | U-238 1.33E-07 | U-238 2.43E-08 | Pu-238 3.24E-09 |
| RH | H-3 5.3E-07 | Pu-238 3.08E-07 | H-3 1.95E-04 | | | | | | | H-3 7.66E-04 | | | | | | H-3 2.80E-05 | | | | |

Notes: Alt. = Alternative; Dec. = Decentralized; Reg. = Regionalized; Cen. = Centralized; RH = remote-handled low-level mixed waste.
[a] Radionuclide contributing most risk.
[b] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this site.

***Table D.3.5–7. Programwide Risks Associated With Treatment of LLMW Under the No Action Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 2.5E+01 | | | |
| | Cancer fatalities | 1.3E–02 | | | |
| | Cancer incidence | 4.3E–02 | 5.7E–04 | | |
| | Genetic effects | 2.5E–03 | | | |
| Noninvolved worker MEI | Dose (rem) | 1.7E–02 | | | |
| | Cancer fatalities | 8.7E–06 | | | |
| | Cancer incidence | 3.0E–05 | 2.1E–07 | | |
| | Genetic effects | 1.7E–06 | | | |
| | Hazard index | | | 4.5E–05 | |
| Offsite population | Dose (person-rem) | 5.7E+02 | | | |
| | Cancer fatalities | 2.8E–01 | | | |
| | Cancer incidence | 1.0 | 2.5E–03 | | |
| | Genetic effects | 5.7E–02 | | | |
| Offsite MEI | Dose (rem) | 7.0E–03 | | | |
| | Cancer fatalities | 3.5E–06 | | | |
| | Cancer incidence | 1.2E–05 | 2.0E–08 | | |
| | Genetic effects | 7.0E–07 | | | |
| | Hazard index | | | 2.3E–05 | |
| WM workers | Dose (FTE-rem) | 2.1E+03 | | | |
| | Cancer fatalities | 8.4E–01 | | | |
| | Cancer incidence | 2.9 | 1.1E–02 | | |
| | Genetic effects | 1.3E–01 | | | |
| | Exposure index | | | 1.2E–02 | |
| | Construction fatalities | | | | 6.0E–01 |
| | Construction injuries | | | | 2.6E+02 |
| | Operation fatalities | | | | 1.1 |
| | Operation injuries | | | | 9.2E+02 |

***Table D.3.5–8. Programwide Risks Associated With Treatment of LLMW Under the Decentralized Alternative, by Health Endpoint***

| Receptor | Endpoint | Radionuclides | Hazardous Chemicals | | Physical Hazards |
|---|---|---|---|---|---|
| | | | Carcinogens | Noncarcinogens | |
| Noninvolved worker population | Dose (person-rem) | 4.7 | | | |
| | Cancer fatalities | 2.4E–03 | | | |
| | Cancer incidence | 8.0E–03 | 1.4E–05 | | |
| | Genetic effects | 4.7E–04 | | | |
| Noninvolved worker MEI | Dose (rem) | 1.5E–03 | | | |
| | Cancer fatalities | 7.3E–07 | | | |
| | Cancer incidence | 2.5E–06 | 7.1E–09 | | |
| | Genetic effects | 1.5E–07 | | | |
| | Hazard index | | | 8.8E–06 | |
| Offsite population | Dose (person-rem) | 3.4E+02 | | | |
| | Cancer fatalities | 1.7E–01 | | | |
| | Cancer incidence | 5.8E–01 | 4.4E–05 | | |
| | Genetic effects | 3.4E–02 | | | |
| Offsite MEI | Dose (rem) | 5.0E–03 | | | |
| | Cancer fatalities | 2.5E–06 | | | |
| | Cancer incidence | 8.5E–06 | 1.2E–09 | | |
| | Genetic effects | 5.0E–07 | | | |
| | Hazard index | | | 1.4E–06 | |
| WM workers | Dose (FTE-rem) | 1.3E+03 | | | |
| | Cancer fatalities | 5.2E–01 | | | |
| | Cancer incidence | 1.8 | 9.7E–03 | | |
| | Genetic effects | 7.7E–02 | | | |
| | Exposure index | | | 1.2E–02 | |
| | Construction fatalities | | | | 2.2 |
| | Construction injuries | | | | 9.2E+02 |
| | Operation fatalities | | | | 1.8 |
| | Operation injuries | | | | 1.5E+03 |