AR TARGET SHEET

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DOCUMENT # DOE/EIS-200-D

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SECTION 4 OF 4

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U.S. Department of Energy
Office of Environmental Management

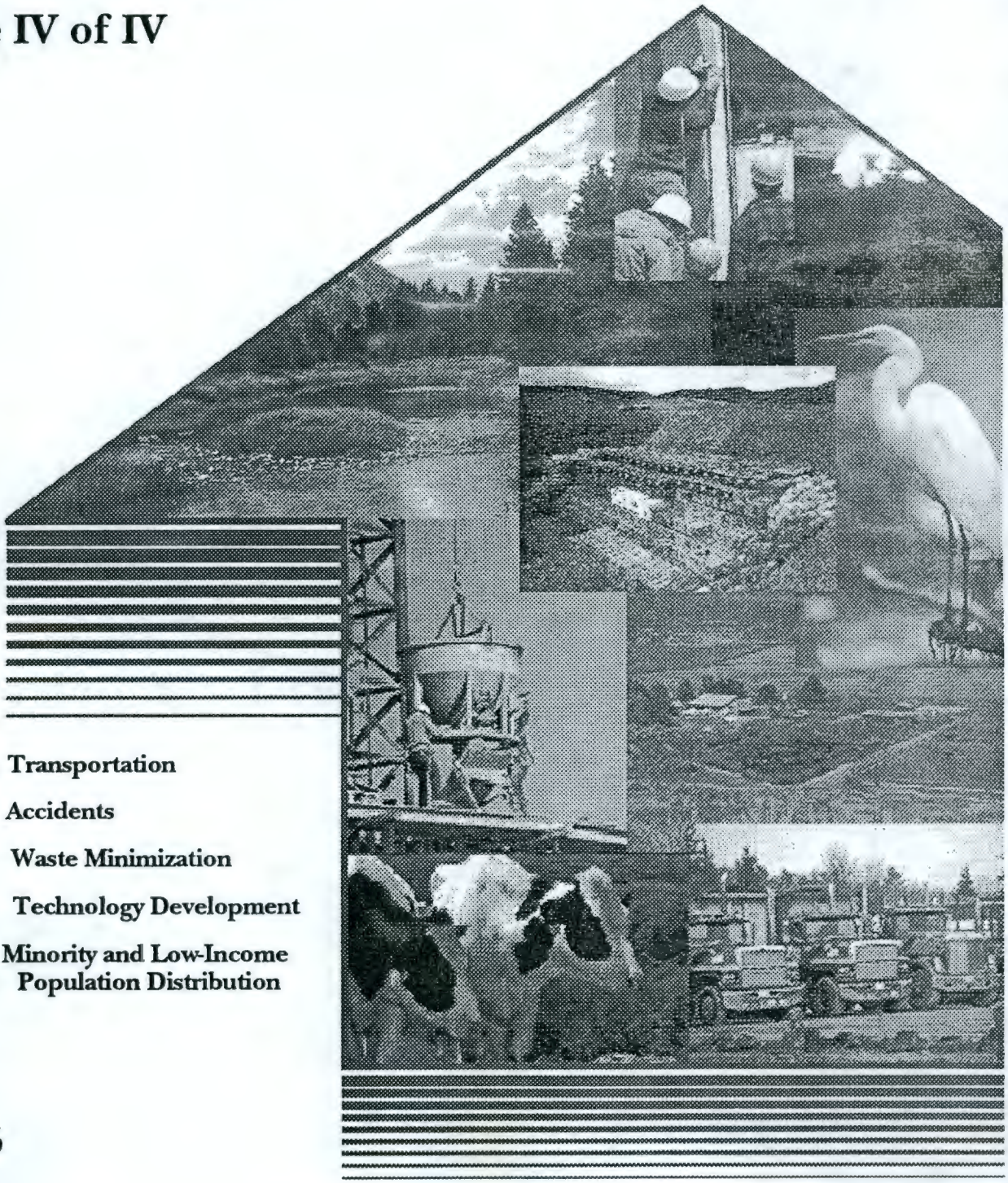
Volume IV

Draft Waste Management Programmatic Environmental Impact Statement

For Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste

Volume IV of IV

DOE/EIS-0200-D



Appendix E Transportation

Appendix F Accidents

Appendix G Waste Minimization

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Appendix I Minority and Low-Income Population Distribution

August 1995

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DOE/EIS-0200-D

DRAFT
WASTE MANAGEMENT
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT
for
Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste

Volume III of IV

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Appendix B Environmental Restoration
Appendix C Environmental Impact Analysis Methods
Appendix D Risk

August 1995

U.S. Department of Energy
Office of Environmental Management
1000 Independence Ave.
Washington, DC 20585

9513387.2093

Appendix A

Public Comments to DOE's Proposed Revisions to the Scope of the WM PEIS

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

August 1995

9513587.2094

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APPENDIX A
Public Comments to DOE's Proposed Revisions to the Scope of the WM PEIS

On June 27, 1989, twenty-two citizens' groups, led by the Natural Resources Defense Council, filed suit to compel the Department of Energy to prepare a programmatic environmental impact statement on proposals for the cleanup and modernization of the nuclear weapons production complex. Consequently, on January 12, 1990, the Secretary of Energy decided to prepare two programmatic environmental impact statements, one on the modernization of the nuclear weapons complex and the other on the Five-year Environmental Restoration and Waste Management Plan. Accordingly, on October 22, 1990, the Department of Energy issued a Notice of Intent (55 FR 42633) to prepare the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (see Attachment 1). In the Notice of Intent, the Department identified the proposed action as follows: "to formulate and implement an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable laws, regulations and standards." The Notice of Intent identified two separate sets of alternatives to be evaluated, one for environmental restoration and one for waste management.

The public scoping period on the Programmatic Environmental Impact Statement extended from October 22, 1990 to February 19, 1991. Beginning on December 3, 1990, the Department held 23 scoping meetings at various locations across the country to ensure adequate opportunity for participation by the public and other government agencies. During the public comment period, over 1,200 people provided approximately 7,000 comments, either by participating in the meetings or by submitting materials and letters. Most concerns were related to the public perception of the Department and to environmental, health, and safety issues.

To record the results of the public scoping meetings and to serve as a plan for preparing the Programmatic Environmental Impact Statement, a Draft Implementation Plan was prepared and made publicly available on February 4, 1992 (57 FR 4193). The Draft Implementation Plan summarized the comments received during the public scoping meetings and identified those issues, as suggested by the comments, that would be considered in preparing the Programmatic Environmental Impact Statement. A public comment period

on the Draft Implementation Plan extended from February 4, 1992 until April 24, 1992. During this time, six regional public workshops were held.

The Final Implementation Plan was completed in January 1994 and made available to the public (59 FR 7990, February 17, 1994). It addressed comments received during the public scoping meetings and those received on the Draft Implementation Plan as well.

Subsequently, the Department attempted to meaningfully analyze the environmental restoration alternatives that it originally defined in the Final Implementation Plan but concluded, after considerable effort, that it would not be appropriate to make programmatic decisions regarding cleanup strategies that would be applicable to all of the Department's sites.

Accordingly, the Department announced on January 24, 1995 (60 FR 4607), an opportunity for public comment on its proposal to shift the focus and change the title of the Programmatic Environmental Impact Statement (see Attachment 2). The proposed modification would eliminate the environmental restoration alternatives and modify the proposed action. On March 16, 1995 (60 FR 14275) in response to a request from the public, the Department announced an extension of the public comment period on the proposed scope to April 10, 1995 (see Attachment 3). In both announcements, the Department stated that the draft PEIS would contain an appendix summarizing comments received during the resulting public comment period.

On April 10, 1995, the Natural Resources Defense Council filed a public comment in response to the notices of opportunity on the proposed modification to the scope and title of the Programmatic Environmental Impact Statement. The Council's comments were the only comments received.

The Council's letter (see Attachment 4) referred to the prior litigation between the Natural Resources Defense Council and the Department of Energy and stated that the Department indicated that its cleanup and waste management activities constituted actions that fall within the meaning of the National Environmental Policy Act and are thus subject to review. The letter also stated that the Department, during the course of litigation, committed to preparing a programmatic environmental impact statement that included environmental restoration.

The Council cited several program-level issues that it believes warrants full analysis and public participation, including those pertaining to uniform versus site-specific standards; the scope and pace of the cleanup program; land use restrictions in setting cleanup levels; inter- and intra-facility priorities in light of budget constraints; and public participation in the decision process for cleanup. Further, the Council noted that as a matter of policy, the Department does not perform reviews under the National Environmental Policy Act for actions taken pursuant to the Comprehensive Environmental Response, Compensation and Liability Act.

The Department agrees that there are issues with regard to the cleanup program for which a national perspective and public discussion are appropriate. These issues concern implementation of the national environmental restoration program, which will involve some broad strategic initiatives and the need for consistency in site-specific decisions to ensure an adequate level of protection and adequate financial controls. DOE is considering some enhanced public participation to obtain input on such national environmental restoration isssues. However, the Department believes that there are suitable analytical tools and venues available other than the programmatic environmental impact statement, to address the issues raised in the Council's letter. These are discussed below.

As the Department notes in the Federal Register Notices of Opportunity to comment on the proposed change in scope, the fundamental reasoning behind its decision to carefully refocus the scope of the draft Environmental Impact Statement was that cleanup decisions should reflect site-specific cleanup conditions commensurate with the regulatory framework under the Comprehensive Environmental Response, Compensation and Liability Act and the Resource Conservation and Recovery Act. The site-specific nature of cleanup decisions is inconsistent with the idea of making decisions under a programmatic environmental impact statement that will be implemented nationwide. In other words, for environmental restoration, there is not a proposed action leading to a programmatic decision in this document. Consequently, a programmatic environmental impact statement is not an appropriate vehicle for analysis.

Arriving at cleanup decisions on a site-specific basis does not preclude public involvement in such decisions, nor does it alter the Department's commitments and requirements to complete appropriate reviews under the National Environmental Policy Act. On the contrary, this permits the necessary specific reviews, considerations, and deliberations for cleanup actions, including considerations of land use issues, to be reached properly with the approval of state and federal regulators and with the direct involvement of the local community.

Additionally, with regard to using land use restrictions in setting cleanup levels, the Department has embarked on an extensive land use initiative to gain an understanding of the long-term future site uses, which is essential to effective planning and decision making for a myriad of Departmental activities. Specifically, this initiative is to provide a basis for cleanup decision making and for site development and comprehensive planning. Each of the Department's major sites is developing future land use preferences with significant involvement of interested and affected stakeholders.

The Department has conducted an ongoing national dialogue with regard to the budget and priorities. The Department actively sought the involvement of regulators and other stakeholders in establishing priorities and developing the FY 1997 budget. The Department designed a process to give regulators and stakeholders a meaningful voice in developing site priorities, which were then used to develop a budget. The goal of this collaborative effort was to plan what could and could not be done with available resources to try to achieve an optimum balance among priorities within a site, and to some extent, between sites. This process resulted in a reprioritizing of activities and modification of schedules to ensure that the program would be as effective and cost-efficient as possible. As part of this open deliberative decision making process, a national meeting was also held with regulators and stakeholders to discuss national priorities and cross-cutting issues as well as any changes to the field budget submission. The pace as well as the scope of the program, therefore, were taken into consideration and are reflected in the priorities and the budget.

With respect to the role of site-specific advisory boards and other means of public participation in the decision making process for cleanup, while not considered an appropriate topic for review in an impact statement, is of critical concern to the Department. The Department has established several advisory boards at its major sites. The boards, which are one means for involving the public, have negotiated their roles and responsibilities. Moreover, agendas are left to the boards, in conjunction with the regulators and the Department, to determine. The boards are informed of ongoing cleanup activities and issues including land use planning, budget planning and development, and priority setting, and are invited into the decision making process.

In the Fiscal Year 1994 National Defense Authorization Acts, Congress directed the Department to provide a life-cycle cost estimate for the program, delineated by specific projects and activities. The Baseline Environmental Management Report systematically analyzed potential life-cycle costs of meeting legal commitments as well as addressing other issues related to the management of hazardous and radioactive materials and waste within the system. The report provided cost estimates associated with various program-

wide alternatives given differing land use assumptions, residual contamination standards funding and schedule changes, waste treatment, storage and disposal options, and potential technology improvements. This report is a valuable analytical tool for exploring cost consequences of potential options.

In addition, the Risk Report, when considered with the Baseline Environmental Management Report as well as other analyses, helps to provide a foundation of technical, environmental, financial, and social analysis needed to inform the national debate on a number of issues, including those raised in the Council's letter. The purpose of the analysis, prepared in response to direction from the Energy and Water Subcommittee of the Committee on Appropriations, was to help the Department develop a mechanism for establishing priorities among competing cleanup requirements.

After careful consideration of the Council's comments, and given these various opportunities for discussion and the analytical tools available to informed debate on national issues, the Department determined that these activities, processes and analyses are useful, but not necessarily sufficient mechanisms to analyze and involve the public in broad environmental strategy issues. Consequently, the Department is considering the addition of some enhanced public participation methods to involve people in the future course of the environmental restoration program to the extent that national decisions and initiatives will occur. Nonetheless, the Department decided that the title and scope of the Programmatic Environmental Impact Statement should be modified as proposed to consider the management of the Department's radiological and hazardous wastes and sites at which the wastes could be managed in the future. This approach is consistent with the alternatives outlined for waste management in the Final Implementation Plan.

As previously set forth in the Final Implementation Plan, the Waste Management Programmatic Environmental Impact Statement will evaluate decentralized, regional, and centralized approaches for storage of high-level waste; treatment and storage of transuranic waste; treatment and disposal of low-level and low-level mixed waste; and treatment of hazardous waste. Waste generated by restoration activities in the future that must be managed as part of the Department's program to manage all of its wastes will be considered in the Waste Management Programmatic Environmental Impact Statement.

Attachment 1
(to WM PEIS Appendix A)

Federal Register Notice
(Volume 55, Number 204, Monday October 22, 1990)
[55 FR 42633]

Department of Energy
"Intent to Prepare a Programmatic Environmental Impact Statement on the Department of Energy's Proposed Integrated Environmental Restoration and Waste Management Program, and to Conduct Public Scoping Meetings"

Federal Register / Vol. 55, No. 204 / Monday, October 22, 1990 / Notices 42853

DEPARTMENT OF ENERGY

Intent To Prepare a Programmatic Environmental Impact Statement on the Department of Energy's Proposed Integrated Environmental Restoration and Waste Management Program, and To Conduct Public Scoping Meetings

AGENCY: U.S. Department of Energy (DOE).

ACTION: Notice of intent (NOI) to prepare a programmatic environmental impact statement (PEIS).

SUMMARY: The Department of Energy announces its intent to prepare a PEIS pursuant to the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321, *et seq.*), as amended, and to conduct a series of public scoping meetings nationwide. The PEIS will assess the potential environmental consequences of alternatives for implementing an integrated environmental restoration and waste management program.

The purpose of DOE's proposed integrated environmental restoration and waste management program is to provide a broad, systematic approach to addressing cleanup activities and waste management practices. The Department is committed to ensuring that potential risks to human health and the environment from the cleanup of contamination resulting from past operations and from future waste management activities are at safe levels. DOE is further committed to full compliance with environmental regulations and to a goal of completing environmental restoration by 2019.

INVITATION TO COMMENT: To ensure that the full range of issues related to this proposal are addressed, comments on the proposed scope of the PEIS are invited from all interested parties. Written comments to assist DOE in identifying significant environmental issues and defining the appropriate scope of the PEIS should be directed to Mr. Wisenbaker at the address indicated below. Agencies, organizations, and the general public also are invited to present oral comments pertinent to the preparation of the PEIS at the public scoping meetings to be held nationwide, as described below. Written and oral comments will be given equal weight.

Following the completion of the public scoping process, a PEIS Implementation Plan will be issued for public comment. The Implementation Plan will record the results of the scoping process and define the alternatives and issues to be evaluated in the PEIS. DOE intends to

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complete the draft PEIS in early 1992. Its availability will be announced in the Federal Register, and public comments again will be solicited. Comments on the draft PEIS will be considered in preparing the final PEIS, scheduled for 1993.

DATES: The public scoping period will continue until February 19, 1991. Written comments should be postmarked by February 19, 1991 to assure consideration. Comments received after that date will be considered to the extent practicable. The public scoping meetings will begin in December 1990. The dates and locations of the meetings will be announced in a subsequent Federal Register notice and in local public notices in advance of the planned meetings.

ADDRESSES AND FURTHER INFORMATION: Written comments on the scope of the PEIS, questions concerning the program, and requests for copies of the draft PEIS should be directed to: Mr. W. E. Wisenbaker, Acting Director, Division of Program Support, Office of Environmental Restoration (EM-43), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585, (202) 353-2950.

For further information on the DOE NEPA process please contact: Ms. Carol M. Borgstrom, Director, Office of NEPA Oversight (EH-25), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585, (202) 586-4600.

PUBLIC SCOPING MEETINGS: Public scoping meetings will be held in the following cities beginning in December 1990. The dates and locations of these meetings will be published in a subsequent Federal Register notice. This information will also be announced in local public notices before the planned meetings.

Oakland, California
Denver, Colorado
Washington, DC
Tampa, Florida
Atlanta, Georgia
Boise, Idaho
Idaho Falls, Idaho
Chicago, Illinois
Paducah, Kentucky
St. Louis, Missouri
Las Vegas, Nevada
Princeton, New Jersey
Albuquerque, New Mexico
Newburgh, New York
Cincinnati, Ohio
Columbus, Ohio
Portland, Oregon
Columbia, South Carolina
Oak Ridge, Tennessee
Amarillo, Texas
Richland, Washington
Seattle, Washington
Spokane, Washington

SUPPLEMENTARY INFORMATION:

Background. In November 1989, the Secretary of Energy established the DOE Office of Environmental Restoration and Waste Management (EM) for the purpose of consolidating the Department's environmental restoration and waste management activities. In January 1990, the Secretary determined that DOE will prepare an Environmental Impact Statement on a newly proposed integrated environmental restoration and waste management program.

Some of the waste management practices that DOE and its predecessor agencies once considered safe and prudent under then existing requirements and guidelines have resulted in the need for remediation under applicable current Federal and state requirements and guidelines. DOE's environmental restoration activities include the assessment and physical cleanup of contamination at DOE installations and other properties. Environmental restoration activities also include the decontamination and decommissioning (D&D) of DOE's surplus facilities. These facilities and properties may have contamination from radioactive, hazardous, or mixed (radioactive and hazardous) waste. As decisions are made for the handling of contamination at various sites and facilities, new wastes will be generated that will require management.

DOE's waste management operations include the treatment, storage, transportation, and disposal of wastes generated by ongoing nuclear energy, energy research, and defense activities; by environmental restoration activities; and by other sources. These wastes include: high-level radioactive waste (HLW); low-level radioactive waste (LLW); transuranic waste (TRU); mixed waste (MW); greater-than-Class C waste (GTCC) waste; and hazardous waste.

The Affected Installations. DOE's environmental restoration and waste management activities occur throughout the U.S. The largest number of facilities that require environmental restoration or that generate or store the largest volumes of radioactive, hazardous, and mixed waste are located at these installations: Hanford Reservation (Washington); Savannah River Site (South Carolina); Oak Ridge Reservation (Tennessee); Rocky Flats Plant (Colorado); Feed Materials Production Center, Mound Plant and Portsmouth Gaseous Diffusion Plant (Ohio); Idaho National Engineering Laboratory (Idaho); Lawrence Livermore National Laboratory (California); Argonne National Laboratory (Illinois); Paducah Gaseous Diffusion Plant (Kentucky); Nevada Test Site (Nevada); Los Alamos National Laboratory and Sandia National Laboratory (New Mexico); and Pantex Plant (Texas). The Appendix contains a listing of DOE locations where current environmental restoration and waste management activities occur that DOE believes are within the scope of this PEIS. Additional sites may be added in the course of the development of the PEIS.

The Regulatory Framework. Federal laws of major importance to DOE's environmental restoration and waste management activities include, among others, the Atomic Energy Act of 1954 (42 U.S.C. 2011, *et seq.*), as amended; the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (42 U.S.C. 9601, *et seq.*), as amended; and the Resource Conservation and Recovery Act (RCRA) (42 U.S.C. 6901, *et seq.*), as amended. The Atomic Energy Act requires the management, processing, and utilization of radioactive materials in a manner that protects the public health and the environment. CERCLA requires responses to releases or threatened releases of hazardous substances into the environment and establishes a process to clean up abandoned or uncontrolled hazardous waste sites which may endanger public health or the environment. RCRA requires management of waste currently being generated, including the treatment, storage, transportation, and disposal of hazardous waste, and cleanup of hazardous waste releases from past and present operations that pose a threat to human health and the environment. It is DOE's policy to apply NEPA to its waste management and cleanup activities. To minimize delay and duplication of effort in meeting these responsibilities, DOE is supplementing, where necessary, and integrating the procedural documentation and public participation requirements for CERCLA and RCRA to facilitate compliance with NEPA requirements (DOE Order 5400.4, Comprehensive Environmental Response, Compensation, and Liability Act Requirements).

DOE environmental restoration and waste management activities are subject to other applicable Federal and state requirements and to enforceable agreements. Additionally, certain Federal statutes require DOE to undertake specific environmental restoration and waste management activities. For example, under Title I of the Uranium Mill Tailings Radiation Control Act, DOE must remediate inactive uranium milling sites in accordance with Environmental

Protection Agency standards (40 CFR part 192) established for that purpose.

Wastes are categorized in accordance with Federal statutes and regulations and DOE Orders. High-level waste is defined in the Nuclear Waste Policy Act of 1982 (42 U.S.C. 10101(12)). Low-level, transuranic, and radioactive mixed wastes are defined in DOE Order 5820.2A (Radioactive Waste Management). Hazardous wastes are those wastes that are defined as hazardous by U.S. Environmental Protection Agency regulations implementing RCRA (40 CFR Part 261) and by applicable state regulations.

Current Practices for Waste Management. To date, DOE's waste management operations have focused on site-by-site treatment, storage, transportation, and disposal of waste. Transuranic, low-level, hazardous, and radioactive mixed waste are generated at many DOE installations; only a few installations generate high-level waste.

DOE generates or stores high-level waste at four installations: the Savannah River Site, the Hanford Reservation, the Idaho National Engineering Laboratory, and the West Valley Demonstration Project. To date, high-level waste has undergone only limited treatment. DOE intends to immobilize the waste in a stable, solid form acceptable for disposal in a geologic repository. Under current law, only one potential repository site (at Yucca Mountain, Nevada) for this waste is currently being characterized.

Most TRU waste has been generated at DOE's Rocky Flats Plant in Golden, Colorado. Transuranic waste is currently stored at several facilities including the Rocky Flats Plant, the Idaho National Engineering Laboratory, the Hanford Reservation, the Oak Ridge Reservation, the Nevada Test Site, Los Alamos National Laboratory, and the Savannah River Site. The Idaho National Engineering Laboratory has the largest management program for this waste. The Department is currently evaluating the Waste Isolation Pilot Plant in Carlsbad, New Mexico, as a potential disposal site for TRU waste.

Low-level waste requires relatively minimal treatment. Although in some instances other methods may be used, DOE currently disposes of the majority of its LLW in near-surface facilities, including installations at the Savannah River Site, the Oak Ridge Reservation, the Nevada Test Site, the Hanford Reservation, Los Alamos National Laboratory, and the Idaho National Engineering Laboratory.

DOE Order 5820.2A (Radioactive Waste Management) requires that the DOE waste equivalent to commercially generated Greater-than-Class C (GTCC) waste be handled as a special case by each site. The Department is also responsible for disposal of commercially generated GTCC waste. DOE has developed a three-part strategy for managing this waste. The first phase would provide a storage facility for those generators that cannot continue to store the waste. The second phase would provide a central storage facility for all commercially generated GTCC waste.

The final phase would transfer the stored waste to a high-level waste repository or provide for the development of a separate GTCC disposal facility.

For hazardous waste, DOE's near-term objective is to treat the waste as it is generated, thereby minimizing the need for storage capacity. DOE disposes of treated hazardous waste in permitted DOE or commercial facilities.

Mixed wastes are generated at many DOE installations. Mixed waste may include high-level waste, transuranic waste, and low-level waste. DOE stores these wastes until they can be treated and disposed of in permitted facilities. The Department currently treats a small amount of MW by thermal destruction to eliminate some hazardous components. In addition, DOE treats some low-level MW by solidification.

The PEIS will address these practices and any reasonable alternatives that are amenable to environmental analysis. (See Scope of PEIS, below)

Current Practices for Environmental Restoration. DOE will continue to seek, to the extent possible, to negotiate a comprehensive Federal Facilities Agreement with the Environmental Protection Agency (EPA) and the involved state to cover its remediation activities at an installation. Such agreements establish technical requirements and schedules for characterization, feasibility assessment and cleanup at each of the affected sites, and delineate the roles and responsibilities of each party to the agreement, to comply with the requirements of Section 120 of CERCLA. DOE is in the early stages of site assessment and characterization at many facilities. These initial activities are being reviewed in compliance with NEPA. DOE has determined that these early remediation activities are normally categorically excluded under its NEPA guidelines (55 FR 37174, September 7, 1990).

Decontamination and decommissioning activities have several objectives: (1) To maintain facilities awaiting additional D&D activities in a manner that protects workers, the public, and the environment; (2) to decontaminate facilities intended for reuse; and (3) decommission other facilities in accordance with requirements set forth in an approved environmental compliance plan. Currently, D&D activities are planned and executed on a site-by-site basis.

The PEIS will address these practices and any reasonable alternatives amenable to environmental analysis.

Need for an Integrated Environmental Restoration and Waste Management Program. The fundamental goal of DOE's Office of Environmental Restoration and Waste Management is to ensure that potential risks to human health and to the environment posed by wastes under its jurisdiction are at safe levels. To help achieve this goal, DOE proposes to conduct an integrated environmental restoration and waste management program.

Historically, DOE environmental restoration and waste management operations have been conducted on a site-by-site basis. This practice has led to differing approaches to cleanup and waste management among DOE sites. DOE's recent consolidation of waste program responsibilities (environmental restoration and waste management) provides the opportunity to establish a systematic approach to programmatic requirements and practices.

Remediation and D & D activities result in large amounts of waste that will require management, in addition to the wastes generated from production, research, and other activities. Because environmental restoration activities will be a significant source of waste, cleanup and waste management activities are closely related. The resolution of certain key issues, such as future land-usability objectives, will determine the amount, type, and timing of environmental restoration waste being introduced into the waste management part of the system. Land-usability policy relates to cleanup standards and the degree of reliance on institutional controls for long-term health and environmental protection.

PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT: On January 12, 1990, the Secretary of Energy determined that a PEIS should be prepared for DOE's newly proposed integrated environmental restoration and waste management program. The Secretary stated that preparation of this PEIS will ensure that a comprehensive and cumulative environmental analysis of waste management proposals and alternatives will be available to DOE decisionmakers and the public.

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The PEIS will assess broad programmatic issues and integrated approaches to DOE's environmental restoration and waste management activities. DOE aims, to the extent this is feasible, for the PEIS to provide the primary environmental basis for selecting waste management methods and technologies and the locations at which they would be implemented. However, DOE does not intend the PEIS to assess impacts related to alternative choices of locations within a site. Such detailed decisions would be based on site-specific NEPA documents tiered to this PEIS.

PRELIMINARY DESCRIPTION OF ALTERNATIVES: *Scope of PEIS.* DOE solicits public input on all aspects of the proposed program described in this notice. DOE plans to structure this PEIS in two sections to facilitate public review and comments. One section of the PEIS will focus on key environmental restoration issues. The second section will analyze reasonably foreseeable potential impacts associated with various waste management alternatives within the integrated program.

As discussed previously, current environmental restoration and waste management practices for which reasonable alternatives that are amenable to environmental analysis can be identified are within the scope of the PEIS. Under the Nuclear Waste Policy Act of 1982 (42 U.S.C. 10101, *et seq.*), as amended, DOE currently plans to dispose of high-level waste resulting from Departmental activities in a repository to be developed for spent fuel from commercial nuclear utilities. In addition, under section 213(a) of the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980 (42 U.S.C. 7272, *et seq.*), as amended, the Department plans to demonstrate the disposal of defense transuranic waste at the Waste Isolation Pilot Plant in Carlsbad, New Mexico. These decisions will not be revisited in the programmatic EIS. In addition, there is a national program, under Congressional direction, to address the management of commercial nuclear reactor spent fuel. The activities associated with that program will be considered in separate NEPA documentation and not in this PEIS. Commercial LLW is not the Department's responsibility and therefore is outside the scope of the PEIS. Uranium Mill Tailings Remedial Action Program (UMTRAP) tailings cleanup and disposal activities are within DOE's purview, but are expected to be close to completion prior to the issuance of the Record of Decision and will not be considered in the PEIS. The groundwater remediation activities associated with UMTRAP are just beginning, however, and therefore are within the scope of this PEIS.

Proposed action. The proposed action is to formulate and implement an integrated Environmental Restoration and Waste Management Program in a safe and environmentally sound manner, and in compliance with applicable laws, regulations and standards. Alternative approaches are discussed below.

Environmental Restoration Analysis:. NEPA requires DOE to analyze reasonable alternatives to its proposed actions. DOE realizes that in the current environmental restoration decisionmaking framework for remediation activities there are statutory and regulatory requirements that must be fulfilled. DOE will continue to follow established processes in conducting ongoing environmental restoration activities.

For example, the framework Congress established under CERCLA for remedial actions imposes a strong preference for permanent remedies that comply with all applicable and appropriate requirements established under environmental laws. Consequently, DOE's overall environmental restoration efforts have focused on cleaning up sites adequately for unrestricted future use. The framework also requires that cleanup requirements and remedies be selected site-specifically. This produces final decisions made both discretely and diversely.

DOE believes, however, that there are important national issues that it should analyze in carrying out its responsibilities. These issues include, but are not limited to, (1) the degree to which DOE should rely on proven technologies in contrast to making strong resource commitments to developing innovative technologies; (2) the manner in which DOE should manage wastes until adequate treatment and disposal capacity is available; (3) whether DOE's installations should invariably be cleaned up for unrestricted use; and (4) the environmental basis for deciding cleanup priorities.

DOE seeks to develop and analyze programmatic alternatives that bear on these issues. DOE believes that important information on the costs and benefits of alternative program management strategies could thereby be obtained. DOE is especially interested in receiving public comments on these issues.

Decontamination and decommissioning activities are not subject to the decisionmaking framework that governs remediation activities. DOE proposes, therefore, to approach all D&D activities in an integrated, systematic fashion.

Waste Management Analysis: Waste treatment, storage, transportation, and disposal alternatives primarily depend on the waste category (such as radioactive, hazardous, or radioactive mixed waste). Alternatives will reflect centralized, regional, or installation-specific strategies. The analysis would provide environmental information for deciding which waste management capabilities should be established centrally, regionally, or at each site. Transportation of waste and the potential associated impacts will also be evaluated.

No Action. This alternative would continue present practices. DOE would not adopt and integrated environmental restoration and waste management program. DOE would continue to operate its environmental restoration activities and its waste operations as discrete site-specific actions. If site requirements dictate the need for offsite or new facilities, management decisions would be made on a project specific basis.

DOE would maintain existing facilities for waste management operations. New waste management activities, projects, and technological development would be considered case-by-case.

IDENTIFICATION OF ENVIRONMENTAL ISSUES: The following environmental issues have been identified for analysis in the PEIS. This list is presented to facilitate discussion on the scope of the PEIS and is not intended to be all-inclusive or to predetermine the scope. Therefore, DOE invites comments on these and additional issues relevant to this PEIS.

(1) The potential impacts (both beneficial and adverse) to worker health, public health, and the environment under various alternatives for environmental restoration and waste management.

(2) The potential impacts to workers, public health, and the environment under various alternatives from routine transportation of wastes and potential transportation accidents.

(3) The development of needed technologies and methods for environmental restoration and waste management and the potential impacts (both beneficial and adverse) from their implementation.

(4) Any obstacles to achieving full compliance with all applicable federal, state, and local environmental statutes, regulations, and requirements.

(3) The socioeconomic impacts of alternatives for dispersed, regional, and centralized waste management.

(4) The potential impacts of applying various land-usability strategies to the cleanup of DOE installations and sites.

RELATIONSHIP TO OTHER ACTIONS: *Five-Year Plan.* DOE issued a Five-Year Plan for Environmental Restoration and Waste Management (DOE/S-0070) in August 1989 that was subsequently revised, updated, and reissued (DOE/S-0078P) in June 1990. The Plan summarizes current DOE practices and identifies short- and long-term goals. The activities described are for the near-term (e.g., remediation of seepage basins at the Savannah River Site, and radioactive storage upgrades at the Kansas City Plant). Only general objectives, criteria, and guidance, in addition to those set in applicable environmental regulations and statutes, are specified for implementing environmental restoration and waste management activities on a long-term basis. For example, the Plan states that the majority of solid low-level waste generally will continue to be disposed of using shallow land burial, but recognizes that this may not be suitable for all locations. The Plan also states DOE's general intent that facilities and sites be returned to a condition suitable for unrestricted use, but recognizes that in-place remedies may sometimes be preferred.

The Five-Year Plan is not a proposal within the context of NEPA. Rather, it is preliminary to the Environmental Restoration and Waste Management PEIS in which DOE will evaluate integrating its long-term environmental restoration and waste management activities. The PEIS will specifically address the long-term goals and issues generally summarized in the Five-Year Plan.

As the Plan states, completion of the PEIS process may result in changes in specific programs, which would be reflected in future editions of the Plan.

Environmental Restoration and Waste Management Configuration Study. The Environmental Restoration and Waste Management Configuration Study is a strategic planning study for the long-term (the next 25 years). The study will support the definition of waste system configuration alternatives in this PEIS. DOE intends to issue the draft configuration study concurrently with the draft PEIS for public information and use in reviewing the draft PEIS.

Many factors influence the configuration and updating of DOE's waste management operations, including: (1) Increasingly strict environmental, safety, and health standards and requirements; (2) facilities dating from the late 1940s to the middle 1960s becoming obsolete; (3) increasing costs to maintain and upgrade these facilities; (4) difficulties in managing widely dispersed waste storage facilities in different environmental settings; (5) potential changes in the locations, volumes, and types of waste to be managed, after consideration of a PEIS on reconfiguring (modernizing) the nuclear weapons complex; (6) availability of improved technologies; (7) population growth near once-remote facilities such as areas near Rocky Flats, Colorado, Fernald, Ohio, Oak Ridge, Tennessee, and Livermore, California, which has led to local demands for restricting DOE operations; and (8) transition from waste accumulation and storage to waste treatment and disposal.

PEIS for the Nuclear Weapons Complex (NWC). In concert with the decision to prepare this PEIS, the Secretary decided that a separate PEIS on DOE's proposal to modernize (reconfigure) the nuclear weapons complex will also be prepared. The reconfiguration of the nuclear weapons complex would affect DOE's program for environmental restoration and waste management because it would change the locations, volumes, and types of waste to be managed. The environmental restoration and waste management PEIS, therefore, will take into account, to the extent practical, the materials generated in the preparation of the NWC PEIS. Separate statements are being prepared, however, because the programs are driven by distinct missions, requirements, and schedules. If the PEIS on the NWC is not issued first, DOE will prepare a supplement to the Environmental Restoration and waste management PEIS, if appropriate.

PUBLIC SCOPING MEETINGS AND INVITATION TO COMMENT: DOE is committed to providing opportunities for the involvement of interested individuals and groups in this and other DOE planning activities.

DOE will conduct a series of public scoping meetings nationwide and invites all interested people to attend and to present oral comments concerning: (1) the scope of the PEIS, (2) the issues that should be addressed, and (3) the alternative integrated approaches to be analyzed in the PEIS. DOE also invites written comments.

Oral and written comments will be given equal consideration. Instructions for submitting written comments are given above. People desiring to speak at the public scoping meetings should submit their requests to do so to the contact persons to be designated in a subsequent Federal Register notice. Oral presentation requests for each meeting should be received by DOE at least two days before the meeting.

The meetings will be chaired by a presiding officer. They will not be conducted as evidentiary hearings. Speakers will not be cross-examined, although the DOE representatives present may ask them clarifying questions.

To ensure everyone an adequate opportunity to speak, five minutes will be allotted for each speaker. Depending on the number of persons requesting to speak, the presiding officer may allow more time for speakers representing multiple parties or organizations. Persons wishing to speak on behalf of organizations should identify the organization in their request. Persons who have not submitted a timely request to speak may register at the meetings, and will be called on to speak if time permits. Written comments also will be accepted at the meetings, and speakers are encouraged to provide written versions of their oral comments for the record.

The public scoping meetings will begin in December 1990. Detailed information on the meetings will be provided in a subsequent Federal Register notice. This information will also be announced in local public notices before the planned meetings.

DOE will make a transcript of each meeting. Copies will be made available for inspection at the DOE Freedom of Information Reading Room (Room 1E-190), Forrestal Building, 1000 Independence Avenue SW., Washington, DC 20585, during business hours, Monday through Friday and in local DOE leasing rooms. Locations of local reading rooms will be provided in the subsequent Federal Register notice regarding the scoping meetings.

RELATED NEPA DOCUMENTATION: DOE expects to prepare additional NEPA documents for implementing programmatic and facility-specific decisions based upon this PEIS. These generally site-specific documents will analyze future technology and siting alternatives for implementing DOE's environmental restoration and waste management activities. Their analyses will address such local concerns as floodplains and wetlands, historic and archaeological sites, land use, and threatened and endangered species. The PEIS will examine these issues only to the degree necessary for selection of an integrated program.

Interim Actions. DOE may need to conduct many diverse and discrete site-

42838 Federal Register / Vol. 55, No. 204 / Monday, October 22, 1990 / Notices

specific environmental restoration and waste management activities while the PEIS is being prepared. Many of these activities are required by Federal and state regulatory agencies under environmental compliance agreements and some are required by court decrees. DOE will have to determine case-by-case whether site-specific actions may proceed before the PEIS is completed. This will be done in accordance with all applicable requirements, including the test for interim actions found in Council on Environmental Quality's NEPA Regulations (40 CFR 1506.1(c)).

Other. DOE has prepared, or is currently preparing, NEPA documents for many of DOE's site-specific actions. Examples of some major relevant waste management NEPA documents are listed below:

1. Final Environmental Impact Statement. Disposal of Hanford Defense High-level, Transuranic and Tank Wastes, Hanford Site, Richland, Washington. DOE/EIS-0113. December 1987. U.S. Department of Energy, Washington, DC.

2. Final Environmental Impact Statement. Waste Management Activities for Groundwater Protection, Savannah River Plant, Aiken, South Carolina. DOE/EIS-0120. December 1987. U.S. Department of Energy, Washington, DC.

3. Final Supplemental Environmental Impact Statement. Waste Isolation Pilot Plant. DOE/EIS-0026-FS. January 1990. U.S. Department of Energy, Washington, DC.

4. Draft Environmental Impact Statement. Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington. DOE/EIS-0119d. March 1988. U.S. Department of Energy, Washington, DC.

These documents, the Five-Year Plan (DOE/S-0078P), transcripts from the public scoping meetings (when they become available), and other related documents will be available for inspection at DOE Freedom of Information Reading Rooms.

Issued in Washington, DC, this 15th day of October 1990.

Peter N. Brush,

Acting Assistant Secretary, Environment, Safety and Health.

Appendix: Locations of Activities Embraced by the PEIS

Name	Location
Amchitka Island	Amchitka Island, AK.
Lawrence Berkeley Laboratory.	Berkeley, CA.
University of California	Berkeley, CA.
Atlantic Interspecies	Canoga Park, CA.
Laboratory for Energy-Related Health Research.	Davis, CA.
Sandia National Laboratory-Livermore.	Livermore, CA.
Lawrence Livermore Laboratory	Livermore, CA.
Bayo Canyon	Los Alamos, CA.
Stanford Linear Accelerator Center.	Palo Alto, CA.
General Atomics	San Diego, CA.
Energy Technology Engineering Center.	Santa Susana, CA.
General Electric Vallecitos Nuclear Center.	Vallecitos, CA.
Rocky Flats Plant	Golden, CO.
Grand Junction Project Office.	Grand Junction, CO.
Project Rulison Site	Grand Valley, CO.
Project Rioblanco Site	Rifle, CO.
Seymour Specialty Wire	Seymour, CT.
Pinellas Plant	St. Petersburg, FL.
Kauai Test Facility	Kauai, HI.
Ames Laboratory	Ames, IA.
Idaho National Engineering Laboratory	Idaho Falls, ID.
Argonne National Laboratory—West.	Idaho Falls, ID.
Argonne National Laboratory—East.	Chicago, IL.
National Guard Armory	Chicago, IL.
Palos Forest	Chicago, IL.
Fermi National Accelerator Laboratory.	Batavia, IL.
University of Chicago	Chicago, IL.
Johnston Atoll	Johnston Atoll.
Paducah Gaseous Diffusion Plant.	Paducah, KY
Ventron, Beverly	Beverly, MA.
Shpack Landfill	Norton, MA.
W.R. Grace & Co.	Curtis Bay, MD.
General Motors	Adrian, MI.
Hazelwood (Latty Avenue)	Hazelwood, MO.
Kansas City Plant	Kansas City, MO.
St. Louis Airport Storage Site	St. Louis, MO.
Mallinckrodt, Inc.	St. Louis, MO.
St. Louis Airport Storage Site Vicinity Properties.	St. Louis, MO.
Weldon Spring Site Remedial Action Project.	St. Charles, MO.
Tatum Dome	Tatum Dome, MS.
Component Development & Integration Facility	Butte, MT
Hallam Nuclear Power Facility	Lincoln, NE.
Du Pont & Company	Deepwater, NJ.
Kellex/Pierpont	Jersey City, NJ.
Maywood	Maywood, NJ.
Middlesex Landfill	Middlesex, NJ.
Middlesex Sampling Plant	Middlesex, NJ.
New Brunswick Laboratory	New Brunswick, NJ.
Princeton Plasma Physics Laboratory.	Princeton, NJ.
Wayne/Pequannock	Wayne/Pequannock, NJ.
Inhalation Toxicology Research Institute.	Albuquerque, NM.
Sandia National Laboratory—Albuquerque.	Albuquerque, NM.
Ross Aviation	Albuquerque, NM.
Project GNOME Site	Carlsbad, NM.
Waste Isolation Pilot Plant	Carlsbad, NM.
Project GASBUGGY Site	Farmington, NM.
Los Alamos National Laboratory.	Los Alamos, NM.
Acid/Pueblo Canyon	Los Alamos, NM.
Chupadera Mesa	White Sands Missile Range, NM.
Central Nevada Test Area	Central Nevada Test Area, NV.
Project Shoal Site	Fallon, NV.
Nevada Test Site	Las Vegas, NV
Tonopah Test Range	Nellis Air Force Base, NV.
Colonie	Colonie, NY.
Niagara Falls Storage Site Vicinity Properties.	Lewiston, NY
Niagara Falls Storage Site	Niagara Falls, NY
Ashland Oil Co. #2	Tonawanda, NY
Linde Air Products	Tonawanda, NY.
Seaway Industrial Park	Tonawanda, NY.
Ashland Oil Co. #1	Tonawanda, NY.
Brookhaven National Laboratory.	Upton, Long Island, NY.
West Valley Demonstration Project.	West Valley, NY.
Reactive Metals Inc.	Ashtabula, OH.
Battelle Columbus Laboratories.	Columbus, OH.
Feed Materials Production Center.	Fernald, OH.
Mound Laboratory	Miamisburg, OH.
Piqua Nuclear Power Facility	Piqua, OH.
Portsmouth Gaseous Diffusion Plant.	Portsmouth, OH.
Albany Metallurgical Research Center.	Albany, OR.
Universal Cyclops	Albulena, PA.
Center for Energy and Environmental Research.	Mayaguez, PR.
Savannah River Site	Aiken, SC.
Oak Ridge National Laboratory	Oak Ridge, TN.
Oak Ridge Gaseous Diffusion Plant.	Oak Ridge, TN.
Y-12 Plant	Oak Ridge, TN.
Pantex Plant	Amarillo, TX.
Hanford Reservation	Richland, WA.
24 Site Covered under Title I of the Uranium Mill Tailings Radiation Control Act.	Various Locations.

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Attachment 2
(to WM PEIS Appendix A)

Federal Register Notice
(Volume 60, Number 15, Tuesday January 24, 1995)
[60 FR 4607]

Department of Energy
"Environmental Restoration and Waste Management; Programmatic Environmental Impact Statement"

Federal Register / Vol. 60, No. 15 / Tuesday, January 24, 1995 / Notices 4607

DEPARTMENT OF ENERGY

Environmental Restoration and Waste Management; Programmatic Environmental Impact Statement

AGENCY: U.S. Department of Energy.

ACTION: Notice of opportunity for public comment.

SUMMARY: The Department of Energy is giving the public the opportunity to comment on proposed modifications to the title and scope of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement. The Department proposes to modify the scope and name of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (PEIS). The proposed action would focus primarily on the evaluation and analysis of waste management issues confronting the Department and would be renamed the Waste Management Programmatic Environmental Impact Statement.

DATES: To ensure that the public's concerns and views are fully considered, DOE is providing a 45-day written comment period that will extend until March 10, 1995, to comment on the proposed modification to the Programmatic Environmental Impact Statement.

ADDRESSES AND FURTHER INFORMATION: Written comments and requests for further information on the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement should be directed to: James A. Turi, Office of Waste Management (EM-33), U.S.

Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585–0002, (301) 903–7147. For information on the Department's National Environmental Policy Act process, contact: Carol M. Borgstrom, Director, Office of NEPA Oversight (EH–25), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585, (202) 586–4600 or leave a message at 1–800–472–2756.

SUPPLEMENTARY INFORMATION: On October 22, 1990, the Department of Energy issued a Notice of Intent to prepare the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (PEIS) (55 FR 42633). In the Notice of Intent and in an Implementation Plan issued in January 1994, the Department identified the proposed action as follows: "to formulate and implement an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable laws, regulations and standards." The Notice of Intent and the Implementation Plan identified two separate sets of alternatives to be evaluated, for environmental restoration and for waste management.

The Department attempted to meaningfully analyze the environmental restoration alternatives that it originally defined as part of the "proposed action." After considerable effort, the Department has concluded that it would not be appropriate to make programmatic decisions regarding cleanup strategies that would be applicable to all of the Department's sites. The fundamental reasoning behind the Department's conclusion is that cleanup decisions should reflect site-specific conditions, and, in any event, can only be reached with the approval of state and federal regulators and the involvement of the public. It would be inconsistent with the site-specific nature of cleanup decisions, therefore, to make these decisions under this PEIS that would be implemented nationwide.

Accordingly, the Department proposes to eliminate the analysis of environmental restoration alternatives and to modify the proposed action. As modified, the PEIS would consider how to manage the subject wastes and analyze alternative sites at which the wastes could be managed in the future. The PEIS would focus its programmatic evaluations on waste management facilities, and would henceforth be known as the "Waste Management Programmatic Environmental Impact Statement." As previously set forth in the Implementation Plan, the PEIS would evaluate decentralized regional, and centralized approaches for storage of high-level waste; treatment and storage of transuranic waste; treatment and disposal of low-level and low level mixed waste; and treatment of hazardous waste. Waste generated by restoration activities in the future that must be managed as part of the Department's program to manage all of its wastes would be considered in the PEIS's projected waste inventories. The draft PEIS is currently scheduled for publication in late spring of 1995.

In the October 22, 1990, Notice of Intent in the **Federal Register**, the Department of Energy discussed the preparation of a Programmatic Environmental Impact Statement based on formulating and implementing an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable requirements. The Notice of Intent stated that the purpose of the integrated environmental restoration and waste management program was to provide a broad, systematic approach to addressing site cleanup and waste management. Although the proposed action was defined in terms of integrating environmental restoration and waste management, the description of the alternatives in the Implementation Plan set forth separate sets of alternatives for environmental restoration and waste management.

When the Department published the Notice of Intent in 1990, there were important national issues regarding the direction of its environmental restoration program that could be meaningfully evaluated in the PEIS. These issues focused primarily on the level and extent of cleanup of the Department's facilities. The Department continues to believe that cleanup of its sites involves important issues such as land use, public health, worker risks, and cleanup standards. The Department has concluded, however, that programmatic decisions regarding environmental restoration cannot be made because these decisions should reflect the particular conditions at each site, and require the approval of state regulators and the involvement of stakeholders. The Department believes that the proposed action originally considered in the PEIS should be modified by eliminating the analysis of environmental restoration alternatives. In view of this modification the PEIS would be renamed the "Waste Management Programmatic Environmental Impact Statement."

The modified proposed action would focus on the evaluation and analysis of waste management issues confronting the Department and would incorporate potential impacts of environmental restoration on the management of wastes. The Department believes the proposed action as modified will identify and analyze waste management issues and activities for which the Department is responsible. A summary of the comments received in response to this notice will be contained in an appendix to the draft Waste Management Programmatic Environmental Impact Statement. Comments previously received during the public comment process on the scope of the PEIS that are still relevant in light of the proposed modification to the PEIS, and the issues raised by such comments, would be evaluated as discussed in the Implementation Plan. Comments on the scope of the PEIS that are relevant to other analyses being conducted in connection with site-specific environmental restoration at DOE's sites will be considered in the preparation of those analyses.

Issued in Washington, D.C., on January 18, 1995.

Thomas P. Grumbly,

Assistant Secretary for Environmental Management.

[FR Doc. 95–1754 Filed 1–23–95; 8:45 am]

BILLING CODE 6450–01–P

Attachment 3
(to WM PEIS Appendix A)

Federal Register Notice
(Volume 60, Thursday March 16, 1995)
[60 FR 14275]

Department of Energy
"Extension of Public Comment Period for The Environmental Management Programmatic Environmental Impact Statement"

[6450-01-P]

DEPARTMENT OF ENERGY

Extension of Public Comment Period for the Environmental Management Programmatic Environmental Impact Statement

AGENCY: U.S. Department of Energy

ACTION: Extension of public comment period.

SUMMARY: On October 22, 1990, the Department of Energy issued a Notice of Intent to prepare the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (PEIS). (55 FR 42633). In the Notice of Intent and in an Implementation Plan issued in January 1994, the Department identified the proposed action as follows: "to formulate and implement an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable laws, regulations and standards." A notice was issued on January 24, 1995, inviting the public to provide written comments on a proposed modification to the scope and name of the PEIS. (60 FR 4607). In the notice, the Department proposed to modify the proposed action to eliminate the analysis of environmental restoration alternatives. As modified, the PEIS would consider how to manage certain types of radioactive and hazardous waste, and analyze alternative sites at which the wastes could be managed in the future. The PEIS would focus its programmatic evaluations on waste management facilities, and would henceforth be known as the "Waste Management Programmatic Environmental Impact Statement."

INVITATION TO COMMENT: In response to a request from the public, the Department is extending for 30 days, until April 10, 1995, the written comment period for the proposed modification to the Programmatic Environmental Impact Statement. A summary of the comments received in response to this notice will be contained in an appendix to the draft Waste Management Programmatic Environmental Impact Statement.

ADDRESSES AND FURTHER INFORMATION: Written comments and requests for further information on the Programmatic Environmental Impact Statement should be directed to: James A. Turi, Office of Waste Management (EM-33), U.S. Department of Energy, 1000 Independence Avenue, S.W., Washington, DC 20585-0002, (301) 903-7147. For information on the Department's National Environmental Policy Act process, contact: Carol M. Borgstrom, Director, Office of NEPA Policy and Assistance (EH-42), U.S. Department of Energy, 1000 Independence Avenue, S.W., Washington, DC 20585, (202) 586-4600 or leave a message at 1-800-472-2756.

Issued in Washington, D.C., this 10th day of March 1995.

Thomas P. Grumbly
Assistant Secretary for Environmental Management

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Attachment 4
(to WM PEIS Appendix A)

Natural Resources Defense Council's (NRDC's) Comments on the Department of Energy's (DOE's) Proposed Modification in Scope of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement
(Letter: Andrew P. Caputo [NRDC] to James A. Turi [DOE], April 10, 1995)

Natural Resources Defense Council

1350 New York Ave., N.W.
Washington, DC 20005
202 783-7800
Fax 202 783-5917

April 10, 1995

James A. Turi
Office of Waste Management (EM-33)
U.S. Department of Energy
1000 Independence Avenue SW
Washington, D.C. 20585-0002

Dear Mr. Turi:

The Natural Resources Defense Council ("NRDC"), lead plaintiff in NRDC v. Watkins, Civ. No. 89-1835-SS (D.D.C.) (stipulation filed Oct. 22, 1990), files the following comments on the Department of Energy's proposed modification in scope of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement. Notice of the proposed modification was published in the Federal Register at 60 Fed. Reg. 4,607 (Jan. 24, 1995), and the comment period was extended to today pursuant to a notice published at 60 Fed. Reg. 14,275 (March 16, 1995).

NRDC opposes the proposed modification for both legal and policy reasons. As a legal matter, the National Environmental Policy Act ("NEPA") requires the Energy Department to prepare a programmatic environmental impact statement ("EIS") on its program of environmental restoration activities, for all of the reasons explained in the submissions by NRDC leading up to and during the above-cited litigation. Moreover, during this litigation the Department specifically conceded that its program of environmental restoration and waste management constitutes "'a group of concerted actions' within the meaning of NEPA,"[1] which triggers a duty to prepare a programmatic EIS pursuant to 40 C.F.R. § 1508.18(b)(3). Finally, the Department committed to prepare such a document in the course of the NRDC v. Watkins litigation.

The case for a programmatic EIS on the environmental restoration program is just as strong from a policy perspective as it is from a legal perspective. While it is certainly true that "cleanup decisions should reflect site-specific conditions," 60 Fed. Reg. at 4,608, it is

1. Memorandum from James D. Watkins, Secretary, DOE, to Leo P. Duffy, Director, Office of Environmental Restoration and Waste Management, DOE, Jan. 12, 1990.

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6310 San Vicente Blvd., Suite 250
Los Angeles, CA 90048
213 934-6900
Fax 213 934-1210

James A. Turi
April 10, 1995
Page 2

equally true that there are a number of important program-level issues relating to the environmental restoration program that demand a full, prospective, program-level analysis with full public participation. These issues include the scope and pace of the environmental restoration program in light of budgetary and other constraints; the choice between using uniform cleanup standards or site-specific cleanup standards as part of the program; the programmatic implications of using land-use restrictions in setting cleanup levels; issues of inter- and intra-facility priority setting, particularly in a situation of budget scarcity; and the programmatic role of site-specific advisory boards and other avenues for public participation in making cleanup decisions. A programmatic analysis of these and other important issues in the environmental restoration program has become even more important in recent months and years, in light of such developments as departmental discussions concerning land-use considerations in the cleanup process, the findings of the Baseline Environmental Management Report, and budget developments.

The need for a program-level analysis of the environmental restoration program is enhanced by the fact that the Department, as a matter of policy, does not perform NEPA compliance on site-specific environmental restoration actions taken pursuant to the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA"). Thus, a program-level EIS seems the only NEPA analysis available to citizens on many of the important issues facing the environmental restoration program. Moreover, no alternative to the NEPA process currently exists for analyzing these issues in a programmatic, prospective manner with full public participation.

Sincerely,

Andrew Caputo

Andrew P. Caputo
Attorney

cc: Assistant Secretary Thomas P. Grumbly

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Appendix B

Environmental Restoration Sensitivity Analysis

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

August 1995

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APPENDIX B
Environmental Restoration Sensitivity Analysis

B.1 Introduction

This appendix provides the Department of Energy (DOE) estimate of waste to be generated by environmental restoration activities throughout the DOE which will require treatment and disposal within the waste management complex. In addition, the appendix presents the methodology used to determine if the addition of the estimated environmental restoration-generated waste loads would effect DOE waste management decisions.

The purpose of the environmental restoration sensitivity study is to identify those alternatives (if any) that are particularly sensitive to the addition of environmental restoration activities and wastes, and to specifically address two questions:

- Will feasible alternatives for waste management become less desirable when environmental restoration-generated wastes are added?

- Does the addition of environmental restoration-generated waste to the planned waste management waste volume increase any impact to an unacceptable level?

B.2 DOE Environmental Restoration Program

A legacy of the Nuclear Weapons Program is environmental contamination at the sites where research, development, test, and production of nuclear weapons took place. The volumes of contaminated media at some locations are quite large. The Environmental Restoration Program was established to address this problem. It encompasses a wide range of activities such as stabilizing contaminated soil, treating groundwater, decommissioning process buildings, including nuclear reactors and chemical separations plants, and exhuming buried drums of waste. The extent to which a site is "cleaned up" will depend largely on assumptions regarding future land use. For most sites, the process of determining future site use has just begun.

The general process to reach decisions concerning cleanup actions is laid out by statutes, including the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC 9601 *et seq*). The process is generally implemented at specific sites through agreements among DOE, the Environmental Protection Agency (EPA), and frequently the host state. The process can be described as follows:

First, a site or portion of a site is "characterized" to identify contaminants, determine the extent of contamination, and assess potential threats to public health and the environment. If significant contamination is indicated, and limited action will result in mitigation of risk, an expedited response action or interim action may be conducted as a means to quickly address the problem. Upon completion of characterization, a detailed analysis is performed to quantify risk and evaluate remedial alternatives. The analysis is followed by a formal decision process including public hearings and formal comment period.

If the results of the analysis indicate that a potential release site is not a threat to health and the environment or that an interim action adequately remediated the contamination, a recommendation of no further action is made to the regulators. If, however, a threat is deemed to be present, the appropriate remediation is identified, and a recommendation is submitted for formal approval. In either case, DOE makes a recommendation on what action is to be taken. The decision on what action will be taken is made by the regulator, not DOE.

During each stage of the environmental restoration process from characterization to final remedial decisions, the potential exists for contaminated media to be generated. The projected volumes of contaminated media to be managed from environmental restoration activities were analyzed by each DOE site during development of the Baseline Environmental Management Report (BEMR) (DOE, 1995). These analyses included consideration of DOE treatment, storage, and disposal capabilities, existing or planned, project-specific restoration requirements, and negotiations with state and federal regulatory authorities in order to estimate what portion of the contaminated media would need treatment, storage, and disposal as a waste within the DOE waste management program. The resulting estimates of these portions of waste are contained in the BEMR as described in Section B.3.

DOE has identified over 11,000 contaminated sites across the complex (PNL, 1995). Contamination at these sites ranges from small areas contaminated from leaking underground storage tanks to large burial pits. A

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complete discussion of the environmental restoration program is in the DOE Pamphlet entitled "Committed to Results: DOE's Environmental Management Program" (DOE, 1994).

B.3 Remedial Waste Estimation Methodology

DOE has commissioned several major studies to prepare projections of environmental restoration-generated wastes and their potential impacts. For the WM PEIS analysis the DOE used waste generation data from the BEMR. The process used to develop environmental restoration waste projections had three major steps: Step 1—estimate the volume of remedial derived waste from each installation, Step 2—define each remedial derived waste stream according to what treatment and disposal would be necessary by the waste management system, and Step 3—adjust the potential volumes according to available DOE installation, field office, and local plans for future land use. The environmental restoration-generated waste volumes that are expected to be provided to waste management do not appear explicitly in the published volumes of the BEMR but were provided from internal BEMR working documents in February 1995.

Table B.3-1 provides the steps used in the WM PEIS analysis for the environmental restoration sensitivity analysis and waste type analysis. In general, the process involves preparing reasonable estimates of the volumes ("loads") of environmental restoration-generated waste that may be handled by waste management, comparing the projected environmental restoration-generated waste volumes with the estimated waste management volumes for each waste type, and then drawing qualitative inferences as to the effect the additional impact might have on a selected waste management alternative. Each waste type chapter presents tables showing the relative percentage increases. Based on this information, conclusions can be drawn for the probable impact of the added environmental restoration-generated waste. This is a study of the *sensitivity* of waste management decisions to the imposition of environmental restoration-generated wastes and not intended to be an absolute statement of the potential impacts from managing these environmental restoration-generated wastes.

B.3.1 Source of Environmental Restoration Data

The amount, schedule, and degree of remedial action will be determined by local decisions within the context of applicable laws and regulations which will define the specific sources, types, and schedules for

Table B.3-1. PEIS Environmental Restoration Sensitivity Analysis Methodology

In Each Waste Type Chapter in the WM PEIS	
Step 1	Select waste management alternatives to represent two bounding cases and one mid-range case for each waste type.
Step 2	Compare the projected environmental restoration-generated wastes as a percentage of the waste management legacy and production wastes for each selected waste management alternative, for each DOE site.
Step 3	Draw conclusions assessing potential of waste management impacts that result from the change in volume due to environmental restoration-generated waste volumes.

environmental restoration waste generation. However, these decisions will occur over an extended time frame as these are made on a site-by-site basis. Secondary environmental restoration-generated wastes were estimated based on a rigorous "bottom up" examination of about 3,500 individual release sites, the DOE site projections based on the current program, and on existing land use agreements.

Table B.3-2 shows the total volume of contaminated wastes expected to be generated by environmental restoration activities. These wastes often require no further treatment before disposal. Some of the remedial actions require treatment and replacement of the contaminated medium (soil, water, debris) within the cleanup unit. In these instances, the contaminated material and its impacts are included as part of the CERCLA action. Because of this approach, these types of remedial actions will produce no wastes requiring treatment and disposal.

Table B.3-2. Summary of Estimated Environmental Restoration-Generated Waste Volumes (Cubic Meters)

	LLMW	LLW	TRUW	HW
Treatment & Disposal	70,266	267,551	1,420	183,188
Disposal Only	120,891	531,599	21,336	64,728
Total	191,157	799,150	22,756	247,916

B.3.2 The Effect on Waste Volumes of Varying Cleanup Goals

The amount of waste, consequent costs, and risks, from individual remedial actions is a direct function of the cleanup goal set for that site. Restoring a site to its original pristine condition will probably generate

the greatest volume of waste. Retaining complete restriction and control over the release site by containing any further spread of contamination will generate the smallest amounts of secondary wastes. An intermediate cleanup goal allowing partial use of the property (e.g., an industrial area) will likely generate environmental restoration waste volumes that fall between the two extremes.

In preparing the WM PEIS, the DOE recognized that cleanup activities are influenced by a combination of the various national and local laws and the desires of local stakeholders on the preferred use of the DOE sites after remediation. Therefore, for each release site, the land use was projected that resulted from probable cleanup goals. The final accumulation and tabulation of waste loads reflects the likelihood that for any given DOE installation, the land uses may be a mixture of the various cleanup levels.

B.3.3 Estimating the Volume of Waste

DOE developed a computer model, the Automated Remedial Action Methodology (ARAM) to examine thousands of release sites. Based on actual release site source term data and on analysis at the sub-release site level, the model estimates waste loads and impacts. To develop environmental restoration-generated waste volume projections for the BEMR, the DOE combined individual DOE site projections based upon the current program with ARAM outputs for releases sites and D&D facilities not yet within the environmental restoration program.

B.4 Assumptions

The scope of this estimate does not include remediation of contamination problems where application of existing technologies would be prohibitively expensive or where their use would cause intolerable ecological damage. Some of the problems facing the Department do not yet have technological solutions. Areas of the Nevada Test Site, where the Department conducted above and below-ground nuclear weapons tests, would be prohibitively expensive to remediate using existing technologies. Remediation of major river systems, such as the mercury contaminated sediments in Tennessee's Clinch River, would cause significant ecological damage because of the necessity to divert river flow to accomplish remediation. Waste loads for these types of environmental problems were not determined for this estimate.

Table B.4-1 summarizes the principal assumptions that form the basis for these projections. This is not an exhaustive list but does provide a general understanding of the underlying assumptions which were used to estimate the environmental restoration-generated waste loads.

Table B.4-1. Assumptions Affecting Environmental Restoration-Generated Waste Loads

- No allowance is made for massive sites, for which no feasible remedial technology is available. (Examples, nuclear test sites, major contaminated aquifers.)
- Some Pre-1970 buried TRUW is excluded if no feasible technology exists for retrieval, (Primarily at SRS). Other pre-1970 TRUW is included (INEL is a major contributor).
- The level, the schedule, and the degree of remedial action are by local decision in the context of regulations and local laws.
- Volume of waste generated is dependent upon the expected land use.
- DOE sites may be geographically divided into separate areas with specific land uses assigned to each.
- Existing land use planning assumptions at a site will be used for the baseline land use.
- Hazardous waste is treated and disposed at commercial facilities to the maximum extent possible.
- Waste from transition of facilities from production to remediation is included in these waste loads.

Table B.4-2 summarizes key assumptions associated with the environmental restoration-generated waste stream characteristics and those that were necessary to conduct efficiently the sensitivity analysis.

B.5 Environmental Restoration-Generated Waste Loads

Table B.5-1 provides a summary of the environmental restoration-generated wastes by waste type that are projected to be generated by environmental restoration activities which would require treatment and/or disposal within the waste management system. Some of the wastes generated by environmental restoration remedial activities are actually stabilized and ready for onsite disposal or for transportation and disposal offsite. These wastes are shown as "dispose" in the waste load tables.

Table B.4–2. Waste Stream Assumptions for the Environmental Restoration Sensitivity Analysis

- LLMW from environmental restoration are all non-alpha.
- Remedial derived TRUW from environmental restoration are all contact handled.
- Treatment for environmental restoration wastes results in disposal volumes at ratio of 1 m^3 yields 1 m^3.
- The relative constituents and treatability categories are assumed to not vary as the amount of environmental restoration-generated waste increases at any location.
- Environmental restoration wastes are assumed to fall into the same treatability groups as the waste management waste of each type and, therefore, can be processed in waste management treatment plants.
- Environmental restoration wastes are assumed to be transported to the same sites as waste management waste for treatment and/or disposal.
- Except where noted, environmental restoration-generated wastes follow the same treatment or disposal configuration as waste management.
- Excess waste management plant capacity can be used for environmental restoration wastes; after planned 10 year production period, 20 years of operational capacity are available to treat environmental restoration wastes without significant additional construction impacts.
- Disposal of environmental restoration wastes requires an equivalent area for disposal as waste management waste.
- Generation of environmental restoration wastes will occur primarily over the thirty-year period from 2003 to 2033.

Table B.5-1. Current Program Environmental Restoration-Generated Waste Volumes to Waste Management

Installation	LLMW		LLW		TRUW		HW	
	Environmental Restoration Waste Load (m^3)		Environmental Restoration Waste Load (m^3)		Environmental Restoration Waste Load (m^3)		Environmental Restoration Waste Load (m^3)	
	Treatment	Disposal	Treatment	Disposal	Treatment	Disposal	Treatment	Disposal
ANL-E		138		2,918				
ANL-W (1)								
BCL		25				71		
BNL		29,250		35,730				
ETEC								
FEMP				86,579				
GA		550		1,740				
GE						20		
GJPO				1				
Hanford								
INEL (1)	15	6,819	1,621	18,333		21,082	229	654
K-25 (1)								
LANL								
LBL		40		42,490				49,752
LEHR		35		892				
LLNL (1)								
Mound				285,236				
NTS				6,030				1
ORNL (1)								
ORR (1)	24,704	24,704	185,518	185,518	1,364	1,364	164,742	164,742
Paducah								
Pantex								
Ports								
RFETS	33,241	115,722	76,210	113,579	56	56		12,878
RMI		5		4,648				
SNL-NM (1)			4,171	15,426				
SRS	12,305	13,869	30	30		163	18,216	19,888
WIPP								
WVDP								
Y-12 (1)								
Total	**70,266**	**191,157**	**267,551**	**799,150**	**1,420**	**22,756**	**183,188**	**247,916**

Note: Amounts for disposal include amounts for treatment.

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Appendix C

Environmental Impacts Analysis Methods

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

August 1995

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APPENDIX C
Environmental Impact Analysis Methods

The Waste Management Programmatic Environmental Impact Statement (WM PEIS) environmental impacts analysis was accomplished using an engineering analysis of generic designs for treatment, storage, and disposal facilities as required to manage each waste type at the sites and estimates of transportation requirements. Outputs from the engineering analysis were estimates of resource requirements, environmental discharges, and costs. These outputs were used as inputs to evaluate human health risks, air quality, water quality, ecological, economic, population, land use, and infrastructure impacts at the sites and in transportation corridors, and were the basis for discussions of environmental justice and cultural resources concerns.

C.1 PEIS Environmental Impacts Analysis Approach

The environmental impacts for the five waste types were evaluated using an analytical process consisting of three phases for the waste management alternatives. This three-phased approach was applied as applicable for each of the waste types at the 17 major DOE sites in the analysis of treatment, transportation, storage, and disposal activities. The three phases, as shown in Figure C.1–1, were: 1) a Generic Design Engineering Analysis Phase; 2) an Engineering Analysis Output Phase; and 3) an Environmental Impacts Analysis Phase.

The environmental resources for which detailed impacts analysis methods are presented in this appendix include:

- **Cost**
- **Air Quality**
- **Water Resources**
- **Ecological Resources**
- **Economic Resources**
- **Population Impacts**
- **Environmental Justice**
- **Land Use**
- **Infrastructure**
- **Cultural Resources**

Engineering Analysis using a Generic Design: In the first phase, DOE made assumptions regarding waste loads for the five waste types. These assumptions related to the volume of waste currently in inventory and anticipated from future operations of DOE facilities and to its physical (gaseous, liquid, solid), chemical, and radiological characteristics. DOE distributed these estimated waste loads among specified DOE sites according to the definitions of the waste management alternatives to determine how much waste would be handled at each site under each alternative. DOE also developed a generic design of the waste management processes and facilities and selected one technology option for purposes of analysis. The facilities considered and the technology chosen for each waste type, and the rationale for that selection, are described more fully in the waste-type chapters.

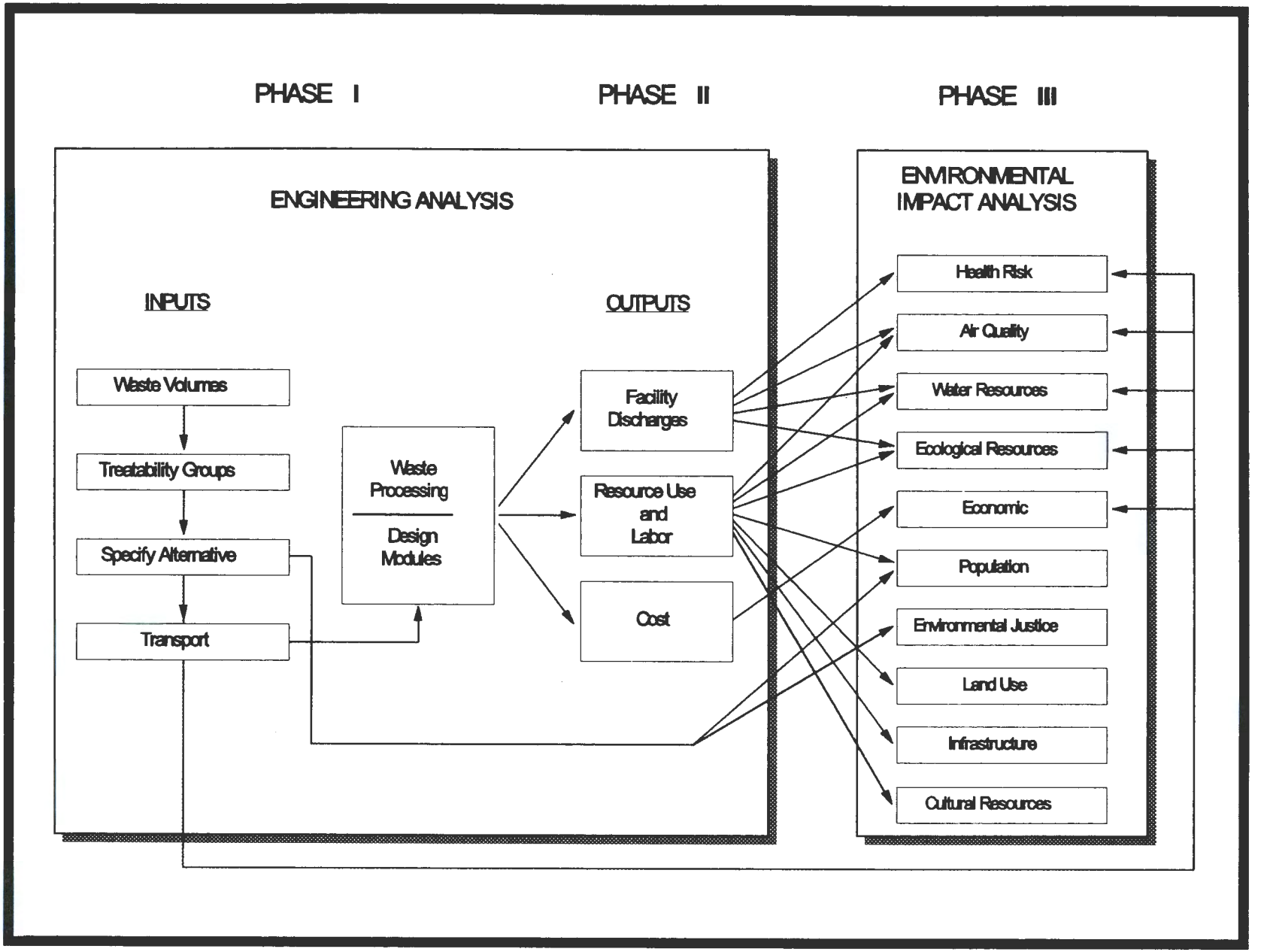

Figure C.1-1. PEIS Analytical Relationships

Engineering Analysis Outputs: In the second phase, the wasteloads allocated to each site under each alternative were generically "processed" through a mathematical model of the generic WM facility design, and estimates of outputs were obtained for the amounts and rates of radiological and chemical effluents released to the environment, volume and rates of resources required or consumed, numbers of full-time equivalent (FTE) workers required, and costs to build, operate, maintain, decontaminate and decommission the WM facilities.

Environmental Impact Evaluation: In the third phase, the effluents, resources, and costs became the input for evaluation of environmental and socioeconomic impacts, and human health risks.

C.2 Phase I: Engineering Analysis using a Generic Design

C.2.1 Waste Loads

Waste Volumes: The PEIS impact and cost analyses used DOE and Environmental Protection Agency (EPA) databases for waste inventories and generation rates. However, these databases are constantly upgraded and a cutoff date was established for the data to allow the analyses to proceed. Sources of data for each of the waste types are listed below:

- **Low-level mixed waste (LLMW)**—The Mixed Waste Inventory Report (DOE, 1994a) was used for all LLMW inventories and generation rates.

- **Low-level waste (LLW), non-mixed transuranic waste (TRUW), and high-level waste (HLW)**—The Integrated Data Base (DOE, 1992a) was used for generation rates and inventories of stored waste. The Waste Management Information System (DOE, 1992b) was consulted for data not available in the Integrated Data Base.

- **Mixed TRUW waste**—The Interim Mixed Waste Inventory Report (DOE, 1993a) was used for mixed TRUW inventories and generation rates.

- **Hazardous waste (HW)**—The EPA Information System biennial reports and DOE Site Inventory Reports were used for generation rates.

The waste loads analyzed in this PEIS do not include wastes that may be generated as a result of environmental restoration (ER) activities. The anticipated ER waste loads are described in the waste- type chapters (Chapters 6 to 10) on a site-by-site basis, and compared to the anticipated WM waste loads at those sites. It is not anticipated that HLW will be generated through ER activities. These chapters also contain a qualitative discussion of the extent to which ER waste loads could affect the conclusions regarding environmental impacts.

Treatability Groups: While this PEIS covers five waste types, those wastes are not homogenous and are derived from thousands of different waste streams. Thus, the wastes were combined into treatability groups for purposes of developing treatment system designs. Each treatability group is identified with one of the five waste types considered in the PEIS and a treatment method, where appropriate, that EPA recognizes as meeting the requirements of the Resource Conservation and Recovery Act (RCRA) (42 USC 6901 *et seq.*). For the PEIS analyses, the physical structure of the waste was used for the initial sort for treatability. At the most basic level of analysis, all waste can be grouped into six physical categories using common engineering criteria design parameters, which also served as the initial set of treatability categories:

- **Aqueous liquids**—Primarily water with organic content less than 1% (such as wastewater)

- **Organic liquids**—Liquids and slurries with organic content greater than 1% (such as solvents)

- **Organic and inorganic sludge and particulates**—Solid and semi-solid material other than debris (such as sludge from treatment plants, resins, and solids less than 2.5-inch diameter particle size)

- **Soils**—Contaminated soils (such as contaminated earth requiring remediation)

- **Debris**—Solid material exceeding 2.5-inch diameter particle size that is either (1) manufactured, or (2) plant or animal matter, or (3) discarded natural or geological material (such as cobblestones)

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- **Other**—Special waste streams (such as batteries, laboratory packs, reactive metals, and toxic metals, which include mercury, lead, and beryllium)

Four waste types use this basic framework analysis: LLMW, LLW, TRUW, and HW. For purposes of the PEIS analysis, HLW, also in the above treatability categories, is assumed to have been treated (vitrified). The PEIS only addresses the environmental consequences of storing and transporting vitrified HLW.

Radiological and Chemical Composition: DOE used standard radiological profiles for each site and made assumptions about the concentration of contaminants in each treatability group based on available data. Hazardous constituents were apportioned to the treatability groups on the basis of the most prevalent hazardous chemicals using an average composition for all DOE sites. The assumptions for both radioactive and hazardous constituents are waste-type specific and are addressed in more detail in the waste-type chapters.

C.2.2 WM TECHNOLOGIES

Various technologies are used to sort and handle waste, reduce waste volume, destroy organic chemicals in waste, remove toxic metals from waste, treat hazardous characteristics to render them non-hazardous, recover and recycle materials, and stabilize and package waste for disposal. The facilities that use these technologies must be designed to accommodate the various physical and chemical forms and the radioactive and chemical characteristics discussed in previous sections. Existing, generic technologies necessary to meet the treatment, storage, and disposal requirements for each waste type were identified and sized to meet anticipated waste volume needs. For analytical purposes, and to facilitate utilization in any system at any site, the waste management technologies were grouped into **common functions** (front-end support such as administrative and laboratory services; receiving, inspecting, dumping, and sorting the waste; maintenance of facilities; and certification and shipping of the waste), **pre-treatment** (shredding and compaction), **primary treatment** (incineration, special processing, neutralization, deactivation, aqueous waste treatment, lead recovery, and mercury separation and recovery), **secondary treatment and stabilization** (polymer stabilization, grout stabilization, packaging, and vitrification of secondary processing residues), **storage** (administration, receiving and inspection, contact-handled

storage, and remote-handled silo storage), and **disposal** (administration, receiving and inspection, shallow land disposal, engineered vault disposal, silo disposal, and borehole disposal).

C.2.3 WM FACILITIES

Treatment, transportation, storage, and disposal "modules" were developed to represent every component required for waste management. Each module was assumed to contain several types of equipment, each able to perform a step needed in the waste management process.

Individual modules were linked together for each treatability group and were adjusted for the chemical and physical type of waste. This method was used so that impacts could be compared among sites, with each site assumed to be using the identical array of linked modules. Any variation in impacts would then result from site-specific environmental differences. This approach also allowed an examination of the changes in impacts resulting from changes in the linked modules.

Typically the type of facility considered was a building structure; i.e., a "fixed" facility at a given site. The analysis also considered the possible use of mobile treatment facilities that could be moved from site to site for treatment of the very small amounts of waste that exist at a number of the sites considered.

The generic design of the WM facility, consisting of these treatment, storage, transportation, and disposal modules, enabled the calculation of land utilization, worker-years, resource consumption (i.e., water and electricity), pollutant discharges, and costs for the treatment, storage, transportation, and disposal of each waste type. The engineering features of the generic facility and the waste loads "processed" through the generic facility formed the basis for the risk and environmental impacts analysis.

For purposes of analysis, the following assumptions were made regarding the construction and operation of the waste management facilities:

- The facilities were assumed to be built over a 10-year period and operated over a 10-year period to process accumulated inventories in a 20-year period.

- The facilities were assumed to operate 240 days per year with three 8-hour shifts.

- Except for HLW, a 20-year period of analysis is generally used for each waste type; the specific assumptions made for HLW are discussed in Chapter 9.

C.2.4 ALTERNATIVES

In the PEIS, an alternative identifies the configuration of sites for treating, storing, or disposing of a specific waste type. Depending on the waste type, certain of these activities may not be analyzed in this PEIS. The categories of alternatives analyzed in this PEIS for each waste type are a no action alternative, decentralized alternative, regionalized alternative, and centralized alternative. These alternatives are described below:

- **No Action Alternative:** These alternatives would involve using only currently existing or approved WM facilities at DOE sites or commercial venders.

- **Decentralized Alternative:** These alternatives would result in leaving waste at the site where it is currently stored or where it will be generated, treated, or disposed in the future. Unlike the no action alternatives, the decentralized alternatives may require the siting, construction, and operation of new facilities or the modification of existing facilities. Under the decentralized alternatives, the WM facilities would be located at a larger number of sites than under the regionalized or centralized alternatives.

- **Regionalized Alternatives:** These alternatives would result in transporting waste to various numbers of sites (fewer than the number of sites considered for the decentralized alternative, but greater than the number of sites considered for the centralized alternatives). Generally, those sites that now have the largest volumes of a given waste type were considered as regional sites for treatment, storage, or disposal.

- **Centralized Alternative:** These alternatives would result in transporting wastes to one or two sites for treatment, storage, or disposal. As was the case with the regionalized alternatives, the sites that have the largest volumes of a given waste type were considered as sites for centralized treatment, storage, or disposal.

These four categories of alternatives encompass the range of reasonable alternatives available to DOE for siting of facilities for the management of the five waste types that are the subject of this PEIS. However, under each category of alternative, there are many possible combinations for the number and location of DOE sites for treatment, storage, and disposal facilities. To narrow these combinations to a number under which a programmatic analysis was feasible, DOE selected particular alternatives for analysis under each category.

The alternatives were developed and defined based on waste type origin and character, volumes and locations within the DOE complex, existing facilities and capabilities, and specialized treatment and disposal requirements. DOE determined where the largest waste volumes are located and where transportation requirements would be minimized. Treatment, storage, or disposal facilities were analyzed at those sites. For example, if seven sites were to be considered under a regionalized alternative, then the seven sites with the largest volume of that type of waste became candidate sites for the analysis. Another regionalized alternative for the waste type being analyzed may evaluate management at three sites; in that situation, the three sites with the largest volume of that type of waste were considered as candidate sites. As shown in Table C.2–1, a combined total of 36 alternatives were evaluated for the five waste types. The waste type chapters (6-10) contain more information on the alternatives analyzed in the PEIS.

C.2.5 Transportation

Transportation is an integral component of the alternatives being considered for the management of each type of waste in the PEIS. The magnitude of the transportation related activities varies with each alternative, ranging from minimal transportation under the decentralized alternatives to significant transportation under some of the centralized alternatives.

Table C.2-1. Number of Alternatives Analyzed in the PEIS

Alternatives	LLMW	LLW	TRUW	HLW *	HW	Total
No Action	1	1	1	1	1	5
Decentralized	1	1	1	1	1	5
Regionalized	4	7	3	2	2	18
Centralized	1	5	1	1	0	8
Total	7	14	6	5	4	36

* HLW alternatives are analyzed in terms of both final disposal beginning in 2015 and final disposal beginning at some later date.

The transportation assessment included the onsite and offsite transportation of radioactive waste. Offsite transportation refers to transporting waste between distinct sites, including parts of the routes that may be within the boundaries of the origin and destination sites. Onsite transportation was evaluated for one sample site; Hanford.

The transportation linkages among generator, treatment, and disposal sites depend on the type of waste and are defined explicitly for each alternative under consideration. For the PEIS, representative offsite truck and rail routes were determined for all possible pairs of origin and destination sites. The routes were selected to be consistent with existing routing practices and all applicable routing regulations and guidelines.

The representative truck routes were determined by using the routing model HIGHWAY 3.1 (ORNL, 1993a). INTERLINE 5.0 (ORNL, 1993b) was used to determine the rail routes. For truck and rail transportation, the route characteristics most important to the assessment included the total shipping distance between each origin and destination pair and the fraction of travel in rural, suburban, and urban areas. Because the routes were determined for the purposes of impact assessment, they are not simply representative of the actual routes that would be used to transport waste in the future.

For the offsite transportation assessment, each specific alternative is defined as a set of pairs (origin and destination) representing shipping linkages among generator, treatment, and disposal sites. The number of origin-destination pairs varies among alternatives, ranging from a small number for the decentralized alternatives, to many pairs for the centralized alternatives. The sites that would not have the capability

to dispose of wastes would ship their wastes to a sites that does. Appendix E contains more detailed information on the transportation analysis.

C.3 Phase II: Engineering Analysis Outputs

The engineering features of the generic facility and the waste loads "processed" through the facility formed the basis for the estimates of resources required, effluents released, and cost. The resources required and effluents emitted, were used to estimate environmental impacts from construction and operation of the WM facilities.

Resource Use

The Waste Management Facility Cost Information (WMFCI) methodology model was used to estimate the resources required for construction and operations of each WM facility. The resources included labor (number of FTEs), land, water, electrical energy, fuel (natural gas, diesel oil, and coal), chemicals, concrete, carbon steel, and stainless steel. A description of the engineering analysis used to estimate the resources used is provided in this section. Details are provided in the WM Engineering Analysis Technical Reports.

Facility Environmental Discharges

Once the generic designs and the volumes and characteristics of the waste and the model throughput requirements were specified, the WASTE_MGMT model was used to estimate discharges from the treatment, storage, and disposal modules. DOE estimated the radiological and chemical components in air and water effluents from processing the waste, and the chemical components in air effluents from the burning of fuel during the operations period. A description of the modeling of effluent releases is given in the Human Health Risk Assessment Technical Report. Section C.4.2 of this Appendix identifies the airborne emissions used in the analysis of air quality impacts. Section C.4.3 provides the estimates of releases from LLMW and LLW disposal units into groundwater that were used in evaluating water quality impacts.

Facility and Transportation Costs

The WMFCI methodology was also used to estimate life-cycle facility costs. Total cost of each alternative include the sum of the treatment, storage, disposal, and transportation costs, and in some instances, special costs. Examples of special costs include the Oak Ridge Reservation "B&C Pond sludge" treatment and disposal actions. Section C.3.2 describes the details of the engineering cost estimation procedures.

C.3.1 RESOURCE USE

The resource use data-estimating process for LLMW, LLW, TRUW, and HW (part of the WMFCI methodology), used the mass/volume throughput to quantify resource consumption for each WM module. Supplemental methodologies provided resource estimates for modular throughputs which were bounded by WMFCI estimates. Samples of tabular presentations of resource use data accompany the discussions. Tabular details are provided (INEL, 1995f). The resource use data estimating process for HLW used regression formulas developed by Argonne National Laboratory (ANL) (ANL, 1995b).

C.3.1.1 Modular Estimating Approach

The resource consumption estimated for each module was dictated by a series of allocation rules. These rules were applied to each module to obtain resource quantities for the module size selected. The resource categories were selected before the actual analysis of any alternatives. During the impacts analysis process, it was determined that several resource categories were not directly needed in the analysis. However, the allocation rules for resources for all facilities are discussed.

C.3.1.1.1 *Construction Resource Use*

The following assumptions were common to developing the resource use parameters for construction activities.

A construction year was defined as 252 workdays, thus allowing time for holidays and weekends. Each workweek is assumed to be 40 hours and composed of five 8-hour days. An FTE employee represents one person working full-time for one construction year, one shift per day.

Most modules were assigned a 2-year construction period, representing the total time assumed from the startup to end of construction activity. A 3-year period was assigned to modules requiring installation of more complex equipment or special construction. The time needed to construct each module was included in tables in the resource use computer code. It was assumed that multiple modules will be placed within a single building. The time required to finish the entire plant is controlled by the interface requirements and staggered delivery schedules normally experienced during construction of a multipurpose facility. On any given site, construction of all required modules was assumed to take three to four years.

Many of the resource use parameters for construction were based on an estimate derived for construction of a generic treatment plant. A 120,000-square-foot generic plant and 3-year construction period were assumed (INEL, 1994).

The module area was a key parameter used in calculating the construction material quantities required. In the construction data tables of the resource use computer program, each construction material quantity is specified in terms of units per square foot. The area was used as a multiplier to calculate the total construction material quantities. The module area was determined from the plant area calculation presented later in this section. All buildings were assumed to be rectangular with a length-to-width ratio of 4:1.

Additional allocation rules for construction socioeconomic resource data included the following for electrical energy, electrical load, fuel, water, laydown area, plant area, parking area, peak employment, and annual costs. Allocation rules for concrete, carbon steel, stainless steel, chemicals, and type of skills which were not used in evaluating environmental impacts are presented in the Environmental Impacts Technical Report.

- **Electrical Energy** (in megawatt-hours): This value represents the total amount of electrical energy consumed during construction.

  Estimate Basis: Electrical energy was calculated by multiplying the connected electrical load, by the hours of use. The hours of use were based on a standard construction year (252 days). The average capacity was assumed to be 65%, which was determined by estimating the electrical energy consumed for construction of the generic treatment facility described above.

The typical allocation of electrical energy during construction was assumed to be 0.017 kilowatts per square foot for all types of facility modules.

- **Electrical Load** (in kilowatts): This is an estimate of the connected electrical sources required during construction.

  Estimate Basis: The electrical load factors for treatment and administration modules were based on the estimates developed for the generic treatment facility described above. The electrical load factor for each module was calculated in kilowatts per square foot of plant area. Total electrical load was obtained by multiplying the module area by 0.017 kilowatts per square foot for all types of facility modules.

  Disposal modules with significantly less construction activity, such as the above-ground disposal module (AGDSP), silo disposal module (SIDSP), and silo storage module (STOSI), had an electrical load factor assumed to be approximately 20% of that of treatment modules. Modules such as shallow land disposal module (SLDSP), which do not include a plant with concrete and metal works, were assumed to have an electrical load factor of only 8%. Borehole disposal (BHDSP) was assumed to be constructed without electricity.

- **Fuel** (in gallons): Fuel oil, gasoline, and propane are included in this parameter. In addition, an allowance of 840 gallons per FTE was assumed to account for fuel used by each employee on the job site and fuel required for travel to and from work.

  Estimate Basis: The fuel factor for construction equipment was based on the fuel consumption estimate for the generic treatment facility described above. A consumption rate in gallons per square foot of plant area per year of construction was derived. A significantly lower value was estimated for the disposal modules. The fuel consumed by construction equipment for each module was obtained by multiplying by the module's area. Fuel consumption during construction for all modules was computed as the module area times 2.35 gallons per square foot of area.

  Fuel consumption by construction employees was estimated by assuming that the workers will travel a 50-mile round trip to the construction site each day of a construction year. A fuel consumption rate of 15 miles per gallon was assumed. This gives 840 gallons per workyear (FTE) for all modules.

- **Water** (in gallons): Estimates for water use include the water consumed during construction activities, potable water consumed by employees, and process water.

  Estimate Basis: The estimate for the amount of water consumed during construction was based on the generic treatment facility estimate described above. The average use of water for dust control, equipment washdown, concrete water, and general cleaning of work areas was determined on a per square foot of plant area basis. A value equal to half of this estimate was used for all disposal and storage modules, based on the fact that fewer construction activities are included with these modules. Total water used for these activities was obtained by multiplying the quantity needed per square foot by the module's area.

  The generic treatment facility estimate was also used to derive the amount of water used by a construction worker per year. The resulting yearly water usage factor was 3,400 gallons per FTE. General construction requirements were 27.5 gallons per square foot of area per year for all modules.

- **Laydown Area** (in acres): The construction laydown area includes the area for each plant module plus that used for equipment and material storage.

  Estimate Basis: The laydown area was estimated by adding a 25-foot-wide buffer to all four sides of the area required for each module. The laydown area for the site was obtained by adding the laydown areas for all modules composing the facility. A length-to-width ratio of 4:1 was assumed for all modules and the buildings containing the modules. The plant area was taken from the calculation below.

- **Plant Area** (in acres): The plant area was obtained by summing the area requirements of the individual modules that constitute the facility. Each module's area was obtained by utilizing a relationship that relates the space required to the module's throughput capacity.

  Estimate Basis: Three different module sizes were used to baseline the cost rollup and resource use data for most modules. Only two were used in a limited number of cases. The area required by any module was obtained by calculating a regression curve relating the three baseline sizes to their throughput capacity. The area needed for any other module was then obtained from this curve, based

on the throughput capacity of the module in question. A scaling factor was applied in instances where the throughput capacity of the module in question was outside the range of the baseline facilities.

- **Parking Area** (in acres): The parking area was obtained by allocating 400 square feet of space to 85% of the number of workers constituting peak employment.

  Estimate Basis: A total individual parking area of 400 square feet was assumed, which includes space for both parking and maneuvering. The number of parking spaces required was based on the peak number of FTEs needed for construction. Parking space was assigned to 85% of this number, assuming that 15% will carpool. Unload/offload was assumed to take place in the laydown area.

- **Peak Employment** (in FTEs): Peak employment is defined as the maximum number of construction employees that will be on the site on any workday during the entire construction period.

  Estimate Basis: The total number of construction FTEs was obtained from the cost rollup data. The total number of FTEs divided by the construction period (in years) provided the average yearly FTEs. Peak employment was estimated as 1.41 (i.e., the square root of 2) times the average number of FTEs per year.

- **Annual Costs** (in $\$\times 1{,}000$): Each of the various average annual construction cost items is divided among labor, material, or equipment categories.

  Estimate Basis: The percentage of labor, materials, and equipment involved in the cost item breakdown was based on previously designed and constructed structures involving similar facilities. This cost information was taken from the cost rollup data.

C.3.1.2.2 *Operations Socioeconomic Resource Use*

The following assumptions were common to developing resource use parameters for facility operations.

An FTE employee represented one person working one shift per day for 252 days per year. Yearly plant operation was taken to be 4,032 hours assuming three 8-hour shifts daily, 240 days per year, with the plant available 70% of the time. The difference between an FTE-year and an operational year allows for the time when an employee may be working but the facility is not operating.

All socioeconomic parameters given for facility operations were annualized.

The module area were also an important factor in calculating operational resource use data. The calculation for module area used in this section is the same as that employed in the construction section.

Additional allocation rules for operations socioeconomic resource data include the following for electrical energy; electrical load; fuel, natural gas or liquid propane gas; fuel, liquid; water; total disturbed area; plant area; total number of worker years; hours per week for labor; O&M labor; operations costs; and maintenance costs.

- **Electrical Energy** (in megawatt-hours): This value represents the total electrical energy consumed during plant operations for one year.

  Estimate Basis: Electrical energy was calculated by multiplying the connected electrical load by the hours of use. It was assumed that the equipment will operate half the time the plant is available. The "hotel load" (i.e., the electricity required for people), in watts per square foot, was multiplied by the module area (from below). Both were multiplied by the hours of use per year. The plant is assumed to operate 4,032 hours per year. This assumes three shifts per day, 240 days per year, with the module available 70% of the time.

- **Electrical Load** (in kilowatts): This value represents the connected electrical load expressed in kilowatts. It was based on the electrical requirements of the equipment in the module plus the hotel load (i.e., the electrical load needed to support human occupancy). The hotel load includes lights, wall plugs, and where appropriate, air conditioning.

  Estimate Basis: The resource use computer code contains estimates for the horsepower requirements of the equipment in the middle (or small) baseline facility. This was converted into watts and multiplied by the ratio of the module's throughput capacity to that of the baseline facility. A scaling

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factor was applied in instances where the throughput capacity of the module in question was outside the range of the baseline facilities.

The code also contains estimates of the hotel load in watts per square foot for each module. The hotel load was multiplied by the module's area and converted to kilowatts. Estimates of the hotel loads for the processing, storage, and administrative modules were based on supporting technical documentation (INEL, 1995f).

- **Fuel, Natural Gas or Liquid Propane Gas** (in pounds): This value represents the fuel needed to heat the building for one year, assumed to be natural gas.

  Estimate Basis: This estimate was based on supporting technical documentation (INEL, 1995f). The calculation assumed that to heat the module for the entire winter, the furnace runs an equivalent of 2 months, 24 hours per day. It was further assumed that 3 British thermal units (BTUs) are needed to heat 1 cubic foot of volume for one hour. Multiplying the module volume by 3 BTUs/hour by 1440 hours yielded the total heat required. One cubic foot of natural gas equals 1,030 BTUs.

- **Fuel, liquid** (in gallons): This quantity represents the fuel required to operate specific pieces of process equipment for one year. Where required, it accounted for operating the equipment at full power as well as maintaining equipment in a hot standby condition. The fuel assumed for these calculations was standard diesel oil.

  Estimate Basis: Some of the modules that process waste require fuel to operate. For those modules, the quantity of fuel required was calculated from the throughput capacity. Tables in the resource use computer program give the quantity needed for each 100 pounds of waste processed. The amount of fuel calculated from the throughput capacity per hour was then multiplied by the hours of operation per year.

  In addition to the fuel needed to process waste, fuel is needed to keep the equipment in a hot standby condition. It was estimated that 75% of the amount needed for operation is required during the hours per year the plant is available. The plant was assumed to operate 4,032 hours per year; three shifts per day, 240 days per year, with the module available 70% of the time.

- **Water** (in gallons): When required, water needed for operating process equipment was calculated specifically for the module in question. In addition, the quantities of water used and consumed by O&M employees were estimated. These were summed to derive the total water used per year.

  Estimate Basis: Some of the modules that process waste utilize water. For those modules, the quantity of water required was calculated from the throughput capacity. Tables in the resource use computer program give the quantity needed for each 100 pounds of waste processed. The amount of water calculated from the throughput capacity per hour was then multiplied by the hours of operation. The plant was assumed to operate 4,032 hours per year, three shifts per day, 240 days per year, with the module available 70% of the time.

  Aqueous waste treatment was assumed to generate 86.7 pounds of water per hour for every 100 pounds of waste mass processed per hour. Incineration was assumed to use 109 pounds of water per hour, grouting 26.1 pounds of water per hour, and mercury recovery 10 pounds of water per hour.

  Each FTE was assumed to use 20 gallons of water per day. The operating year for water use was taken as 252 days. The total water used was the sum of that used by the processing equipment and that used by the O&M personnel.

- **Total Disturbed Area** (in acres): The disturbed area required for an individual module was assumed to encompass a space with sides 10 feet from the area needed for processing or other activities. The module was assumed to be rectangular with sides in a ratio of 4:1. The disturbed areas for each module were summed and the area of the parking lot added to yield the total disturbed area for the plant.

- **Plant Area** (in acres): For each module, this value represents only the area needed for conducting the stated operation. The total facility area is a simple sum of the individual module areas that make up the facility.

  Estimate Basis: Three different module sizes were used to baseline the cost rollup and resource use data for most modules. Only two sizes were used in a limited number of cases. The area required by any module can be obtained by calculating a regression curve relating the three baseline sizes to their throughput capacity. The area needed for any other module was then obtained from this curve,

based on the throughput capacity of the module in question. A scaling factor was applied in instances where the throughput capacity of the module in question was outside the range of the baseline facilities.

- **Parking Area** (in acres): Parking space was assigned to each FTE. Visitor parking was accounted for by assuming 15% of the FTEs will carpool. Unload/offload parking was assumed to be included within the plant area.

  Estimate Basis: The number of FTEs was obtained from the cost rollup data by dividing the total number of O&M FTEs by the number of operating years. A total of 400 square feet was assigned to each FTE. This total included both parking area and maneuvering room.

- **Total Number of Worker Years** (in FTEs): This value, in FTEs, was taken from the cost rollup data. An FTE represented one person working an 8-hour shift for 1 year composed of 252 days.

- **Hours per Week for Labor** (in hours): A total of 40 hours was assumed.

- **Types of Skills as a Percentage of Total Skills** (in percent):

  Operating Labor: The total labor pool (i.e., the total number of O&M FTEs) less the number required for maintenance.

  Estimate Basis: The average annual number of FTEs needed for both operations and maintenance was obtained from the cost rollup data. This number is equal to the total number of O&M FTEs divided by the number of operating years assumed for each module. The percentage of FTEs used for operating labor was obtained as follows: First, maintenance labor cost was calculated based on the equipment cost (see below). Next, the number of annual FTE maintenance employees was obtained by assuming each worker has an expense of $140,000 per year. The annual number of FTE operating personnel was obtained by subtracting the number needed for maintenance from the total average annual number of O&M FTEs. The ratio of annual operating FTEs to the total annual average O&M FTEs yielded a percentage.

Maintenance Labor: Annual maintenance labor was assumed to be equal to a percentage of the equipment cost plus a contingency factor. Equipment costs were obtained from the cost rollup data.

Estimate Basis: The annual number of maintenance FTEs was calculated as follows. First, the maintenance costs for labor were estimated by assuming that the labor costs are equal to 250% of the maintenance material costs for each module. The maintenance material costs were taken as a percentage of the equipment cost (between 3% and 7% depending on the module). By assuming each FTE cost was $140,000 per year, the total number of maintenance FTEs was calculated. The ratio of annual maintenance FTEs to the total annual average O&M FTEs yielded a percentage.

- **Maintenance** ($×1,000): Annual maintenance costs were composed of two factors, material and labor. These values were estimated as a percentage of the cost of the equipment.

  Estimate Basis: Maintenance cost was based on the equipment cost. It is assumed that 3% to 7% of the equipment cost was spent annually for maintenance materials, and the cost of maintenance labor is 2.5 times the material costs. To derive the total maintenance cost, a 25% contingency factor was added to this sum.

- **Operations** ($×1,000): Operating costs constitute all costs needed except those required for maintenance.

  Estimate Basis: The total annual cost of O&M was obtained from the cost rollup analysis. The annual cost was obtained by dividing the total cost by the number of operating years assumed for each module. The number of operating years was also obtained from the cost rollup data. The annual cost of operations was obtained by subtracting the maintenance costs (from above) from the annual O&M cost.

C.3.1.3 Resources Associated With Portable Modules

Small generator sites typically generate very small quantities of certain wastes. Where portable modules were used (TRUW and LLMW), resource consumption was identified for each portable module and its contribution was rolled up into the site resource totals.

C.3.1.4 Resource Data Estimate Methodologies for the PEIS Alternatives

To analyze resources, the PEIS waste volume data were first divided into four waste types: LLW, LLMW, TRUW, and HW. These waste types were then subdivided into cases to analyze the alternatives. The cases were subdivided according to handling characteristics, sites, and construction or operations activities. Generic technology modules were identified and sized to meet the treatment, storage, and disposal requirements for each case. Resource data results were compiled for each alternative by summing the various resource data components for each module, then summing the module results for each site (DOE, 1995a).

For some alternatives, supplementary extrapolation methodologies were applied. The data for these alternatives were obtained from similar data computed as described in Sections 3.1.1-3.1.3, then scaled based on either cost or waste processing rates. The supplemental resource methodologies used for LLW, LLMW, TRUW, and HW can be found in Waste Management Environmental and Socioeconomic Impacts Methods and Results (DOE, 1995a).

C.3.2 Cost Estimating

Costs were estimated using an approach that tied the cost of facilities and transportation to waste quantities. In addition, DOE used costs associated with existing technologies and historical industrial cost experience for estimating purposes.

C.3.2.1 Cost-Estimating Process Details

Each alternative includes a definition of the assumed technologies for the complete treatment process. For each site and each alternative, wastes were hypothetically routed through the waste management process, and the modules were individually sized to handled the processing requirements. Since many sites have existing treatment, storage, and disposal capabilities (INEL, 1994), the analyses accounts for existing facilities to minimize additional construction requirements. However, only O&M costs were estimated for existing facilities.

C.3.2.1.1 *Waste Management Facility Cost Information Reports*

The PEIS used a set of reports, collectively referred to as the "WMFCI reports," to develop cost and manpower estimates for the various alternatives and cases being considered. These reports were prepared for DOE by EG&G Idaho to provide a generic facility costing and resource use estimating methodology for programmatic analysis of treatment, storage, disposal, and inter-site transportation of radioactive and hazardous waste. The WMFCI reports consist of the following:

- Data extracts of the detailed facility equipment and construction estimates and other costing factors applied to base estimates for waste types

- Management analysis reports summarizing the findings of the data extract reports according to waste type

- Procedural reports that describe how to compute costs and manpower for the modules used for the treatment, storage, and disposal of waste types

- Data reports computed by PEIS alternative/case by waste type for cost and FTEs, and for resource consumption data supporting the environmental impacts analysis

The WMFCI reports provide a consistent and defensible basis for generating life-cycle cost information for treatment, storage, and disposal facilities using specific data for each major waste type. The WMFCI reports present cost and manpower information reports for LLMW, LLW, TRUW, and HW. (INEL, 1995a; INEL, 1995b; INEL, 1995c; INEL, 1995d). Within the waste-type categories listed above, cost information was developed for alpha-contaminated wastes (both LLW and LLMW) and RH waste (LLW, and TRUW). For some treatment processes, costs for portable systems were developed for non-alpha contaminated waste (LLW and LLMW); these were deemed more realistic and lower cost approach for treating extremely small waste loads. A separate report (INEL, 1995e) was developed to provide a cost computation methodology applicable to the shipment and routing information provided in Appendix E for the transportation of radioactive and hazardous wastes. A full listing of WMFCI reports is provided in the references cited section of this appendix.

The WMFCI reports were developed specifically for DOE-owned facilities. The cost-estimating used in the reports included provisions necessary to comply with all applicable regulatory requirements for a particular waste type and to meet the requirements of all applicable DOE orders. Indirect costs and overhead burden rates used in the WMFCI reports were based on those historically encountered at DOE's Idaho National Engineering Laboratory (INEL), which fall approximately in the middle of the range of cost factors found at several other DOE sites and which are, therefore, considered to be representative for complex-wide estimating purposes.

C.3.2.1.2 *Modular Estimating Approach*

To facilitate the development of comprehensive cost estimates covering cradle-to-grave management of wastes, the WMFCI reports categorized all necessary WM activities into a series of modules, each representing a discrete facility that carries out a single WM function. A unique set of cost information was developed for each WMFCI module (see Table C.3-1). Within a given module, a series of unit operations necessary to accomplish the specified function was defined in sufficient detail to enable development of the planning level cost information. For example, the incineration module included each of the following unit operations: feed preparation, incineration, secondary combustion, and off-gas treatment. The array of unit operations is sufficiently broad to accomplish the incineration tasks required by the identified waste inventories.

Once a particular WM alternative-based scenario was defined, a series of modules was selected that best represented all activities required to accomplish the necessary WM functions. Some scenarios may have required only 1 or 2 modules to fully define the WM functions, while others may have required 10 or more modules to capture all necessary functions. This modular approach to establishing the cost-estimating basis provided maximum flexibility; thus, the WMFCI was designed to be the full used to support a broad range of WM options.

Design of the WMFCI was based on standard, proven technologies and WM approaches. The modules represent a variety of treatment, storage, disposal, material handling, and support facilities, that were developed for all major DOE waste streams. The cost modules, are listed by waste type in tables found in (INEL, 1995f).

Table C.3-1. Facility Cost Modules Included in WMFCI Reports

Module	LLW	LLMW	TRUW	HW
Treatment Front-end Support	x	x	x	x
Small Generator Front-End/Back-End Support	x	x		
Waste Characterization			x	
Packaging	x	x	x	
Stored Waste Retrieval			x	
Receiving and Inspection	x	x	x	x
Open, Dump, and Sort	x	x	x	
Assay, Sort, and Package				x
Maintenance	x	x	x	
Incineration	x	x	x	x
Aqueous Waste Treatment		x	x	x
Neutralization	x		x	
Shredding/Compaction	x	x	x	
Supercompaction	x			
Metal Melting	x	x		
Wet-Air Oxidation		x		
Thermal Desorption		x		
Debris Washing		x		
Soil Washing		x		
Lead Recovery		x	x	
Mercury Separation		x	x	x
Organic Removal				x
Deactivation		x	x	x
Special Waste Processing	x	x	x	
Recycling				x
Organic Stabilization			x	
Grout Stabilization	x	x	x	x
Polymer Stabilization	x	x		
Vitrification	x	x	x	
Certification and Shipping	x	x	x	x
Storage Front-End and Back-End Support	x	x	x	
Storage Receiving and Shipping			x	
Storage	x	x	x	
Silo Storage	x		x	
Disposal Front-End Support	x	x		
Engineered Disposal	x	x		
Shallow Land Disposal	x	x		x
Silo Disposal	x	x		
Borehole Disposal	x	x		

Note: HLW facilities are covered in a separate report (ANL, 1995b) but included only storage facilities.

C.3.2.1.3 *Cost-Estimating Basis*

A "bottom-up" estimating approach was used to develop the WMFCI unit costs. Initially, a capacity range for each facility cost module was established by studying the currently stored and future projections of DOE waste volumes. Process functional diagrams and facility layout drawings were developed at the individual unit operation level. After all unit operations required for a module were defined, major equipment lists, building configurations, and square footage requirements were established, and cost estimates for each facility were developed.

Data from the study defined baseline capacities for five facility sizes: portable, minimum-fixed, small, medium, and large. Using the five facility sizes, a generic design package for each cost module was developed and used as the basis for the Program Life Cycle Cost (PLCC) estimates. Each design package included a summary functional and operational requirements description, a process functional diagram with mass flow rates, a facility layout, manpower requirements for the processes, and cost and manpower (FTE) capacity-to-requirement curves. The design packages used as much available data from existing or planned DOE facilities as possible. This approach, referred to as "anchoring," provides the reference point used to estimate the various cost components. New designs were generated only if no existing data were available.

C.3.2.1.4 *Cost Components (Work Breakdown Structure)*

The costs for each WM facility included the following four components (each estimated separately): (1) pre-operational activities, including the costs of studies, demonstrations, generic designs, permitting, and startup; (2) facility construction, including definitive design, equipment and building, and construction labor costs; (3) O&M costs; and (4) decontamination and decommissioning (D&D) costs. Usages were determined separately for resources used during the construction period (which includes pre-operations and construction) and resources used during the period of operations (which includes O&M, and D&D).

Resource usage was estimated for all treatment, storage, and disposal facilities configured at each site for each waste type under each alternative. Building unit costs for various functions were developed by generating detailed material quantities, labor hours, and related costs for construction, using rates applicable to INEL. These building functional unit costs were multiplied by the functional floor space

required within each module. The functional cost sub-totals were summed to give a total building cost for each module.

Equipment costs were estimated either by soliciting budgetary costs from suppliers, by using existing data, or by making engineering judgments. Costs for the other three components of the estimate (operating budget-funded activities [pre-operation], O&M, D&D) were obtained from actual costs of existing facilities and from engineering estimates. These cost components do not include various site costs for the supporting infrastructure and basic site services known as "chargebacks." The allocation rules for chargebacks are site-specific and provide a similar site effect for all alternatives. They do not affect the relative cost ranking of the alternatives, and are not included in the PEIS.

To provide a comprehensive analysis of the WM facility requirements for support, the facilities required to manage the waste (for example, administration and maintenance) were also provided as separate facility cost modules. This approach facilitated analysis of scenarios that involve existing facilities where none, some, or all of the administrative functions may have already been in place.

C.3.2.1.5 *Cost Estimates Development*

To assist in application of the WMFCI, the baseline cost/capacity relationships defined for each cost module were translated into parametric cost relationships. These relationships were defined by linear and log-linear equations that uniquely define the costs over a broad range of capacity requirements. Each facility module had specific cost equations that defined the pre-operations costs, facility construction costs, O&M costs, and D&D costs. The cost relationships allowed the WMFCI to be consistently applied over a wide range of estimating scenarios.

Both DOE and the commercial nuclear industry have facilities similar to some of the cost modules examined by the WMFCI. Several facilities (for example, incinerators, metal-melters, supercompactors, SNF storage, and engineered disposal) were surveyed to obtain functional and operational requirements, capacity limitations, capital and operating costs, and other information needed to provide a basis for the WMFCI data.

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To the extent possible, major equipment costs in each cost module were taken from similar facilities that had been constructed or that were in the advanced design stage. Before using costs from existing facilities, the data were adjusted to account for capacity differences and escalation. These cost validation steps established a cost confidence level for the PLCC estimates of plus or minus 30%.

Facility construction costs were based on the current cost-per-square-foot rates for five typical building functional envelopes defined by use—low hazard, moderate hazard, alpha-treatment, storage, and disposal functions—planned and under construction at INEL.

C.3.2.2 PEIS Cost-Estimating Methodology

C.3.2.2.1 *Description of Alternatives*

Cost estimates for each PEIS alternative were developed at the module level for each site within the DOE complex. For a given WM alternative, every site with waste of that type played a role in management of that waste and consequently incurred some cost. The roles of the various sites could have ranged from simply packaging and shipping their own wastes to treating and disposing their own wastes and wastes from other sites. The contribution each site made toward the cradle-to-grave management of a given waste type was defined in each alternative through designation of treatment, storage, and disposal locations for each site's waste. The alternatives generally covered the range of possible configurations from a centralized waste management strategy to a decentralized scenario. Other parameters that were also varied within the alternatives analyzed for a particular waste type included the level of treatment performed and the final waste form produced. Therefore, for each alternative, a unique set of responsibilities was defined for each site; this established the activities that had to be performed at each site and provided the basis upon which the cost estimates were developed.

C.3.2.2.2 *Waste Loads Development*

Once the WM activities to be performed at each site were defined for a particular alternative, the quantity of waste to be processed or handled through each module was calculated. This step was accomplished

using a set of "raw" data that accounted for all waste stored and generated at each site. The waste information included quantities of waste currently in storage and projections for future waste generation. Each classification of waste (LLW, LLMW, TRUW, and HW) was broken down into "treatability groups." The treatability groups, based on the characteristics of the waste, helped to define which treatment processes were necessary to meet regulatory requirements for that waste type. (The generic configurations of processing modules necessary to treat, store, and dispose each waste treatability group were discussed earlier.) The raw data were transposed into the waste loads for each facility by applying the constraints and assumptions integral to the configuration designated for each alternative. Once a time factor was incorporated (for example, a 10-year operating period), the waste load for each module became a waste processing rate. The processing rates (throughput capacities) for each module was used to determine facility size and was the key factors used in developing the cost estimates.

C.3.2.2.3 *Existing Facilities Assessment*

A survey of existing and planned-or-approved WM facilities at each site, and their capacities, was performed to provide the baseline for cost-estimating purposes. Where existing capacities were identified, the total required operating capacity was reduced by that amount so that only the minimum necessary new facility construction was costed. Since existing facilities and their capacities were taken into account, the cost estimates developed for each alternative could be considered to be representative of actual future capital investments necessary to provide the additional capabilities required for the WM operations outlined in each alternative.

In some alternatives, where a homogeneous waste stream was currently being treated in a dedicated facility and actual operating costs were known, these actual costs were used in the PEIS cost estimates (rather than using bottom-up cost estimates for generic facilities designed to treat the same waste).

C.3.2.2.4 *Bounding Parameters and Assumptions*

The PEIS alternatives generally assumed that a 10-year implementation period was necessary to construct and start up the new WM facilities required for each alternative, and that a 10-year operating period would be used to work off the projected waste inventories.

Costs under the no action alternative for each waste type were estimated using a unique set of assumptions. The no action alternatives (with some exceptions for storage and disposal) used existing facilities for 20 years. Where projected waste loads exceeded existing treatment facility capacities, waste was assumed to be stored.

The HW alternatives were assumed to use commercial treatment and disposal contractors for 20 years; possible regional on-site treatment and disposal costs were also evaluated.

Costs associated with treating quantities totaling less than 0.1 pounds per hour or disposing quantities totaling less than 0.1 cubic feet per hour were considered to be insignificant and costs were not developed. These volume totals equate to treating a drum or less of waste per year and disposing 60 drums (one semi-trailer load) or less of LLW or LLMW per year. In such instances, bench-top-type treatment, or shipment to another facility, would be likely to occur.

The receiving and inspection module was used only for wastes received from another site for regionalized or centralized treatment. It was assumed that wastes generated on site would be characterized to the extent that inspection would not be required and that the waste could be transported directly to the treatment facility. Representative sampling of on-site waste characterization was assumed to be performed as necessary through a variety of modules: certification and shipping (found at all sites), administration—with laboratory—(found at all treating, storing, and disposing sites), and waste characterization (found at all TRUW sites).

The "open, dump, and sort" module was used only for waste volumes currently in storage. It was assumed that these containerized wastes are heterogeneous and would need to be sorted before treatment. It was further assumed that wastes presently being generated or to be generated in the future would be segregated by treatment need and would not require sorting.

Except for TRUW, it was assumed that treated wastes would be accumulated in small batches (railcar or truckload quantities) and would be shipped directly for disposal, eliminating the need for storage. For TRUW, it was assumed that shipment could not be made directly to WIPP; therefore, costs were estimated for one year of storage before transportation to WIPP.

C.3.2.2.5 *Application of the Waste Management Facility Cost Information Methodology*

Curves for cost-versus-capacity and FTEs-versus-capacity were developed for each module through a bottom-up estimating method. These curves were developed over a finite range of capacities (referred to as the "standard capacity range") that, at the time the range was selected, would fit the anticipated cost-estimating needs. The standard capacity range selected was specific to each module. Cost versus capacity curves were developed for equipment (including installation), building requirements, operating labor, and operating materials. From these curves all other costs were determined through application of various cost factors. Combining all derived costs produced the life-cycle costs for each module. Costs for all modules were based on a 48-week year, three shifts per day, 5 days per week, and 70% availability, for a total operating period of 4,032 hours per year. The 4,032 hour year is a "rating" of achievable production capacity possible in a full 52-week workyear.

Curves for cost versus capacity were developed for numerous modules handling CH LLMW, CH alpha-LLMW, RH LLMW, CH LLW, CH alpha-LLW, CH TRUW, RH TRUW, and HW. FTEs-versus-capacity curves were determined by applying a factor to the costs for an appropriate category.

With the release of updated waste data, the need for costs at capacities outside the standard capacity range of developed data became necessary. The following methodology was used to estimate the costs when the capacities fell outside the standard range for any particular module.

C.3.2.2.5.1 <u>Costs Determination for Treatment Outside Standard Capacity Range</u>

To estimate the costs for a treatment module at a throughput capacity falling below the standard range, the following extrapolation method was used. An "economy of scale" function was assumed to exist beyond the upper and lower bounds of the capacity-to-cost curve (developed as discussed above). The upper and lower bounds were the waste processing throughput capacities of the largest and smallest standard commercially available processing equipment for the particular module being adjusted. The basic formula is shown below:

[Cost for higher/lower capacity] =[Cost for high/low bounding point] × [(waste throughput capacity of higher/lower requirement)/(waste throughput capacity of high/low bounding point)]$^{0.7}$

The ratio of required throughput capacity to the throughput capacity of the high or low bounding point of the capacity-to-cost curve was raised to the 0.7 power. The use of the 0.7 power scaling factor was based on estimating methods presented by Peters and Timmerhaus, and Remer and Chai, Chemical Engineering, April 1990. The resulting value was used to adjust the cost of the equipment, building requirements, operating labor, and operating materials. These adjusted costs were then used to estimate the costs associated for the lower-than-standard capacity (to eliminate unrealistically small modules). A module was never scaled down to below 10% of the smallest capacity in the standard range. Similar judgment would have been used when scaling to modules several times larger than the upper bounding capacity; however, waste loads never became that large, so this approach was not tested.

For the incinerator module and the small generator front-end support module, costs were developed for a module of "minimum" size designation. This represented the smallest module size that could be constructed with off-the-shelf equipment. A slightly different approach was used to estimate costs. For capacities falling between the minimum capacity and the lowest capacity in the standard capacity range, the costs were determined by the method described above. For capacities falling at or below the minimum, the "minimum module" capital cost was used and operating costs were scaled down from the minimum capacity using the 0.7 power factor method. To eliminate an unrealistically small module for very small capacity requirements, the number of shifts was limited to 0.1 shift per workday.

For seven other non-alpha modules (aqueous waste treatment, wet-air oxidation, thermal desorption, deactivation, lead recovery, mercury separation, and polymer stabilization), the minimum module was the same as the lowest capacity in the standard range. Costs for these seven modules were treated in a parallel manner as stated for incineration (above). For capacity below the range associated with these seven modules, capital costs from the minimum module were used and the operating costs were scaled down from the minimum capacity using the 0.7 power factor method.

To determine the costs of an engineered disposal module (AGDSP) or a shallow land disposal module (SLDSP) at a capacity falling below the standard range (18 to 126 cubic feet per hour), the following extrapolation method was used. For disposal capacities within the standard capacity range (1.44 to 5.9

cubic feet per hour) for the silo disposal module (SIDSP), costs for silo disposal were used. For disposal capacities falling between the standard ranges of the SIDSP and the AGDSP or SLDSP (5.9 to 18 cubic feet per hour), the ratio of the actual capacity to the lowest capacity of the AGDSP or SLDSP standard capacity range was raised to the 0.7 power. The resulting factor was used to adjust the cost of the equipment, building requirements, operating labor, and operating materials. These adjusted costs were then used to estimate the associated costs. For disposal capacities falling below the standard capacity range of the SIDSP, costs were determined by scaling down with a factor developed by taking the ratio of the actual capacity and the smallest capacity in the standard range for the SIDSP raised to the 0.7 power.

C.3.2.2.5.2 Portable Module Costs

Small generator sites typically generate very small quantities of certain wastes. To treat these small quantities, installation of permanent treatment facilities would not always be cost effective. To handle these small quantities, portable treatment modules were identified as an economical alternative. Portable modules were used for certification and shipping, decontamination, polymerization (which is capable of performing grout stabilization for very small volumes), thermal desorption, and wet oxidation (which could substitute for incineration for very small volumes).

Costs for portable treatment modules were developed based on processing 2.5 cubic meters of waste per treatment campaign. Waste to be processed was assumed to have an incoming density of 40 pounds per cubic foot for all modules, except aqueous waste, which has a density of 62.4 pounds per cubic foot. Each treatment campaign was assumed to require 2 weeks, including setup, processing, and shutdown. Counting travel time and equipment maintenance time, the number of campaigns was limited to 12 per year. (If waste quantities were sufficiently high to exceed 12 campaigns per year, permanently installed modules were estimated.) The portable equipment was assumed to have a useful life of 5 years, or 60 campaigns. A host facility (warehouse, garage, or similar structure) with suitable utility support was assumed to be required.

Costs associated with portable modules were developed on a campaign basis. Each portable module has its unique campaign cost, computed to include all programmatic life-cycle cost components.

C.3.2.2.5.3 Supplemental Cost-Estimating Methods

For most WM alternatives, costs, manpower, and resource use data were computed using the above-described methodology. The computations were made by selecting the same data results from cases estimated using the WMFCI methods in LLW Cases 5, 7, 12, and 14 for cost/manpower and in Cases 1, 2, 4, 5, 7, 12, 14, and 14a for resource data; in HW Case 1 for cost/manpower and Cases 1 and 2 for resource data; in TRUW Cases 1, 10, and 11 for resource data; and in LLMW Cases 1, 7, 10, and 17 for resource data. For certain data points, exact matches did not exist; in such instances, data were scaled linearly, using waste processing throughput proportions, from the nearest data point computed using the WMFCI method. These computations are summarized in Sherick and Shropshire, 1995. Resource use data estimates were discussed in part C.3.1.

Where modifications to the originally computed data were required because of changes in costing assumptions, a similar "exact selection, or scaling from closest data point" method was used. These computations have been summarized (INEL, 1995f).

In the case of HLW, cost and manpower estimates for canister storage and transportation were abstracted from the many cost studies performed for vitrification of HLW at the West Valley Demonstration Project (WVDP), Savannah River Site (SRS), Hanford, and INEL. A summary of these findings is found at Section C.3.2.2.8.

C.3.2.2.6 *Transportation Cost Estimates*

Transportation costs were calculated for each alternative using mileage between sites (either by highway or rail) and mass quantities requiring shipment. Transportation costs were included for waste shipments between generator sites and treatment sites, between generator sites and disposal sites, and between treatment sites and disposal sites. Costs were compiled for each alternative for both truck and rail transportation. Transportation costs for most waste types were computed using linear regression formulas, where a fixed cost per trip (depending upon waste type) was multiplied by the number of shipments and added to a variable cost-per-loaded-mile multiplied by the total shipping mileage. The fixed and variable costs per waste type and the background of the transportation cost-estimate development are provided (INEL, 1995e). The cost-estimating process for the transportation of HLW is found at Section C.3.2.2.8.

C.3.2.2.7 *Quality Assurance*

The PEIS cost estimates were compiled for each alternative, and the detailed estimating backup information is documented in data packages retained in the PEIS engineering files. Each cost data package was thoroughly reviewed before publication of any cost results. The quality reviews verified that the estimating methodology was correctly and consistently applied, that the assumptions and alternative descriptions were followed, and that the results provided reasonable PLCC that can be used to compare the relative costs of the various alternatives.

C.3.2.2.8 *Cost-Estimating Procedures for High-Level Waste Canister Storage and Transportation*

The generic cost methodology used was modified to reflect the specific assumptions for HLW. These modifications are discussed below.

C.3.2.2.8.1 Methodology and Assumptions

The life-cycle costs are the "cradle to grave" costs, incurred from the time the waste is generated to the end of its institutional control. The total life-cycle costs include all costs associated with waste handling following its generation, current storage and treatment, transportation, future disposal and monitoring. The WM PEIS does not provide cost analysis of the current storage of HLW, pretreatment and treatment of HLW (resulting in canisters of vitrified waste), or environmental impacts of HLW disposal. The WM PEIS does provide cost analysis of the storage of canisters and the transportation to storage sites and a candidate geologic repository. Because of the possibility of a prolonged delay of HLW disposal, two sets of timing assumptions for acceptance of HLW at the candidate repository were analyzed.

Projecting the cost of the HLW alternatives involved developing estimates of the individual cost components. The cost was divided into two components—capital investment and annual operating charges. The capital cost of a facility was assumed to include process equipment, construction materials (for example, steel and concrete), and labor, as well as indirect costs such as those for design, contingencies, and environmental compliance. The annual O&M costs were expenses estimated for O&M staff, fixed and variable supplies, annual operating fees, administration, and general expenses. These two cost

components were estimated by reviewing and abstracting available data on the costs of storage and transportation of HLW (ANL, 1995b).

C.3.2.2.8.2 Canister Storage

Vitrified HLW from Hanford, SRS, WVDP and INEL would be placed in on-site storage facilities awaiting transport to the candidate geologic repository. The WM PEIS alternatives for HLW management include: (1) No Action—Continued storage (assumed for 30 years), (2) Decentralized—All sites provide storage for canisters until the candidate geologic repository begins accepting DOE HLW in 2015, with shipments beginning in 2016; (3) Regionalized 1—WVDP ships its canisters to SRS for storage until transportation to the candidate repository starting in 2016; (4) Regionalized 2—WVDP ships its canisters to Hanford for storage until transportation to the candidate repository begins in 2016; and (5) Centralized—WVDP, SRS, and INEL ship their canisters to Hanford for storage until transportation to the candidate repository begins in 2016. For the alternatives, the assumption was made that the approval of the candidate repository will occur in a timely manner so that the amount of storage facilities to be constructed could be kept to the minimum required.

The second set of timing assumptions is configured identically to the No Action, Decentralized, Regionalized 1, Regionalized 2, and Centralized Alternatives, except that acceptance of DOE HLW at the candidate repository is deferred past 2015, requiring the construction of storage facilities at each site capable of holding the full amount of canisters to be stored at that site. These alternatives are costed assuming that the approval of the candidate repository is made in time to begin transportation in 2016 but after each site has completed construction of storage facilities for all canisters produced at that site. Further deferrals of the decision will increase the total cost of storage. Depending upon the alternative, the costs for storage operations will increase by an additional $8 million for every year past 2015 that acceptance of HLW canisters at the candidate geologic repository is delayed.

The storage technology selected for costing is the modular dry vault storage (MVDS) concept. It is assumed that the interim canister storage facility at Hanford and at SRS for the vitrified HLW would hold canisters in vertically sealed cavities within a concrete structure forming the storage vault. Each canister storage vault (CISV) will be an air-cooled dry storage vault for vitrified HLW. A thermosyphon ventilation system would be used to remove heat generated by the stored vitrified HLW. Activities at a

given CISV include receipt and unloading of transportation cask containing canister(s) of vitrified waste, inspection of the canister, and storage of the waste until transfer to a permanent geologic repository. The CISV consists of rows of tubes or vaults laced below grade into which the canisters are lowered. Concrete plugs provide a cover for the tubes. The canisters are to be stored in sealed sleeves so that the cooling air would not directly come into contact with the potentially contaminated surfaces of the HLW canisters. Although the design for storage of canisters at INEL has not been decided, the PEIS assumed the storage technology to be the same as that for Hanford and SRS. Because the storage facility has been constructed at WVDP, these costs are not included in the PEIS analysis.

The rationale for costing the construction and operations of these facilities is provided (ANL, 1995b). The cost experience for monitored retrievable storage facilities was modified to the above concept. The below formula was developed to estimate capital costs:

Formula C-1

$$[\text{Capital Cost (\$ million)}]_{MVDS} = 0.71\ [\text{Capacity (HLW Canister)}]^{0.53}$$

Annual O&M costs include the routine handling, storage, and retrieval, with the predominance of costs pertaining to the operation of facilities. The operating lifetime of the various storage facilities varies depending upon the transportation instruction for each Alternative. The correlation of the annual operating costs for the storage period as a function of capacity is:

Formula C-2

$$[\text{Annual O\&M Cost (\$1,000/yr)}]_{Storage} = 38.6 + 0.27 \times [\text{Capacity (HLW canisters being stored)}]$$

Loading/unloading operations were evaluated in the reference; the following formula was developed:

Formula C-3

$$[\text{Annual O\&M Cost (\$1,000/yr)}]_{Loading} = 770 \times [\text{Throughput (HLW Canisters shipped/yr)}]^{0.52}$$

With respect to the shipping rate to be assumed for the various alternatives, the loading rate into storage is taken to equal the maximum annual vitrification rate (190 canisters per year for SRS, 790 canisters per year for Hanford (No Action is 320 canisters per year), 300 canisters per year for WVDP, and 327

canisters per year for INEL). The total time for unloading the HLW canisters before shipment to the candidate repository is assumed to be performed at a rate of 800 canisters per year. The loading/unloading duration is dependent upon the shipping rate.

The quantities and timings shown in Chapter 9 were applied to the formulas C-1, C-2, and C-3, and totaled for each alternative under both sets of timing assumptions. The computation summaries are provided (INEL, 1995f).

C.3.2.2.9 *Transportation of Vitrified HLW Canisters*

The rationale for costing transportation of HLW canisters between sites is provided in Folga, et al., 1995. Based on numerous reports, there is general agreement that transportation costs for HLW would be similar in cost for spent nuclear fuel. The life-cycle cost for HLW transportation can, in general, be calculated by summing the following cost categories: shipping cost; security cost; cask, capital and decommissioning cost; cask maintenance cost; inspection cost; demurrage cost; handling cost (loading and unloading); and transportation support system costs.

The following assumptions were made for the HLW transportation cost analysis:

- The costs associated with the inspection cost category are included in the annual operating charges for the various HLW storage facilities.

- Demurrage (the charge for the detention of a freight car or truck by the shipper or receiver beyond the time allowed for loading, unloading, or shipping) is assumed to be negligible in comparison with other cost components.

- The handling cost for loading and unloading at the HLW storage facility has already been considered in the storage cost; the handling cost at the candidate repository is assumed to be out-of-scope for this PEIS.

- Transportation support system cost include the costs to maintain the railcars and trailers which are assumed to be negligible (average annual O&M cost for a truck trailer is approximately $14,000; for a rail car, $5,000).

Table C.3-2 presents the formulas used to compute truck and rail transportation costs.

C.4 Phase III: Environmental Impacts Evaluation

This section describes the scientific approach and analytical methods used to evaluate the impacts of the WM alternatives on air quality, water resources, ecological resources, the local and National economies and social environments, environmental justice issues, land use, infrastructure, and cultural resources.

Table C.3-2. Assumed Relationship for the Four Transportation Cost Components

Cost Variable	Relationship Assumed in This Study	
	Rail-Based	**Truck-Based**
SPEED (mph)	DIS/(0.04204 x DIS + 4)[a]	35 (i.e., a constant value)[b]
Annual Cask Requirement, ACR	Σ {[(2 x DIS)/$SPEED_{rail}$]/24 + 2 x (5 days)}[c]	Σ {[(2 x DIS/$SPEED_{truck}$]/24 + 2 x (3 days)}[c]
Shipping Cost, less than 1,000 miles ($1985)	Σ ([2.32 + 0.0067 x DIS] x 2,000) + ([2.15 + 0.0063 x DIS] x 1,800) x [No. of Canisters]/5[c,d]	Σ ([1.493 + 0.0033 x DIS] x 500) + ([0.428 + 0.0034 x DIS] x 475) x [No. of Canisters][c]
Shipping Cost, greater than 1,000 miles ($1985)	Σ ([5.07 + 0.004 x DIS] x 2,000) + ([4.72 + 0.0037 x DIS] x 1,800) x [No. of Canisters]/5[c,d]	Σ ([-0.16 + 0.0049 x DIS] x 500) + ([-0.19 + 0.004 x DIS] x 475) x [No. of Canisters][c]
Security Cost ($1985)	Σ {291.65 x [$DIS^{-0.5987}$] x DIS} x [No. Of Canisters]/5	Σ {7.93 x [$DIS^{-0.1855}$] x DIS} x [No. of Canisters]
Cask Capital Cost ($1985)[e]	Σ (ACR/300) x [No. of Canisters] x (2.5×10^5)	Σ (ACR/300) x [No. of Canisters] x (1.5×10^5)
Cask Maintenance Cost ($1985)[f]	Σ (ACR/300) x [No. of Canisters] x (2.5×10^4)	Σ (ACR/300) x [No. of Canisters] x (1.5×10^4)

[a] DIS = distance traveled (one-way miles); is a function of WM PEIS alternative.
[b] Conservative value, based on [DOE, 1986]; a value of 40 mph is cited in [DOE, 1991].
[c] The summations are to be performed over all shipping routes.
[d] Assumes five HLW canisters per rail shipping cask, one HLW canister per truck shipping cask [DOE, 1986].
[e] Assumes a capital cost of $2.5 million for rail cask, $1.5 million for truck cask (both in $1985 dollars) [DOE, 1986].
[f] Assumes an annual maintenance cost of $125,000 for rail cask, $75,000 for truck cask (both in $1985 dollars) [DOE, 1986].

The general impacts methods were applied as appropriate to analyze the effects of management alternatives for each of the five waste types. Construction and operation of treatment, storage and disposal facilities and intersite transportation of wastes were the principal activities analyzed for impacts, as applicable (Table C.4–1) under each of the waste-type alternatives.

The engineering analysis Phase II output data served as the input data for the environmental impacts assessments. These engineering outputs included estimates of the costs, labor, and resources required to build and operate the WM facilities and estimated facility discharges of pollutants to air and water.

Table C.4–1. WM Actions Analyzed for Environmental Impacts

WM Action	Waste Type				
	LLMW	LLW	TRUW	HLW	HW
Treatment Facility Construction and Operation	✓	✓	✓		✓
Storage Facility Construction and Operation	✓*		✓	✓	
Disposal Facility Construction and Operation/(& Postclosure Effects)	✓	✓			
Transportation of Wastes Between Sites	✓	✓	✓	✓	✓
Waste Transport to Repository or Commercial Treatment/Disposal			✓	✓	✓

* For No Action Alternative only.

Air quality impacts were analyzed by comparing estimated pollutant increases to applicable standards for the Air Quality Control Region at each site. The analysis addressed criteria pollutants, airborne radionuclides and other hazardous and toxic air pollutants from construction and operation of WM facilities at each DOE site. Criteria pollutant increases from mobile (transportation) and stationary sources were evaluated, as applicable.

Water resources impacts were analyzed by evaluating the effects on natural water sources of the use or discharge of large volumes of water during construction or operation of WM facilities at each site. Water quality impacts were evaluated for hypothetical releases of waste, that could leach into groundwater the releases were assumed to come from deteriorating packages or containers in disposal facilities.

Ecological impacts were evaluated in terms of the potential for loss of habitat from site clearing for WM facility construction, indirect facility construction and operation effects on sensitive habitats, exposure of terrestrial species to airborne contaminants released from treatment facilities, and a scenario-based assessment of the consequences of releases of wastes to aquatic habitats in transportation accidents.

Economic impacts were analyzed by estimating job and income increases in the regional economies supporting the DOE sites that might be caused by the infusion of funds to build and operate WM facilities. Impacts on the National economy were also assessed using the sum of all expenditures at all sites and for waste transportation under each waste-type alternative.

Population impacts were evaluated in terms of changes caused by the influx of labor for construction and operation of facilities.

An analysis of environmental justice considerations —disproportionate effects on minorities or low-income populations—discusses and displays the minority and poverty status of the populations at each WM site to highlight sites where those populations might be disproportionately affected by WM activities.

Land use impacts were evaluated by estimating the likelihood that building WM facilities at the sites under a WM alternative would require a commitment of land that might substantively alter the use of land at the site or that might require DOE to acquire additional land to implement the alternative. Conflicts with site development plans and current adjacent land uses were also considered.

Infrastructure impacts were evaluated by estimating the effects of building and operating WM facilities on site water supply, waste water treatment facilities, electrical power supply, and transportation infrastructure. Community infrastructure impacts were evaluated in terms of the estimated level of increased demand on community infrastructure caused by the influx of new labor and their families to support the WM projects.

The potential for cultural resources effects was considered comparatively in terms of the extent of construction site disturbance at each site under each alternative as an indicator of the requirement for cultural resources surveys that would be conducted at the site or project level. Impacts on cultural resources were not evaluated directly because the WM facility locations on each site are not yet proposed.

Environmental impacts considered in the PEIS, but not evaluated in detail, included effects on geology and soils, the noise environment, and visual resources. Those impacts are discussed in Chapter 5 of the PEIS.

All chemical and radiological discharges and direct radiation effects were estimated using computer models that simulate the fate and transport of contaminants in the environment. The computer models are described in the sections on air quality, water resources, and ecological resources. The models are further described in the facility risk appendixes (D and F) and the transportation risk appendix (E).

C.4.1 Human Health Impacts

Human health effects were evaluated for all aspects of the construction and operation of treatment, storage, and disposal facilities, for transportation of wastes, for accidents involving facilities at the sites, and for transportation accidents. Details of the human health risk assessment that estimated risks at the facilities during routine construction and operations activities and during facility accidents are given in Appendix D. Details of the routine transportation and transportation accident risk assessments are given in Appendix E. Further details of the facility accident risks are given in Appendix F.

C.4.2 Air Quality Impacts

Air quality impacts were determined for pollutant-emitting activities associated with managing each of the five waste types: LLMW, LLW, TRUW, HLW, and HW. Air quality impacts were assessed for the construction of new treatment, storage, and disposal facilities; for the O&M of the facilities; and for shipment of wastes between sites. The following sections describe in detail the methods used to estimate the air quality impacts for each WM alternative.

C.4.2.1 Air Quality Impacts Analysis Methods

Air quality impact assessments predict the consequences in terms of deterioration in air quality at off-site locations resulting from the release of contaminants from various categories of pollutant sources. This PEIS evaluated the potential for any of the alternative WM actions to lead to deterioration of local or

regional air quality at any of the sites. The analysis also evaluated the potential for the actions across sites, in combination with pollutants emitted in the waste transportation corridors, to lead to deterioration of National air quality.

C.4.2.1.1 *Air Pollutants Considered*

The air quality impacts analysis estimated the air emissions for WM facility construction and O&M activities. O&M activities include waste treatment, storage, disposal, and transportation of waste. Estimates were made for each action for four classes of air pollutants: (1) the criteria air pollutants regulated under the National and State Ambient Air Quality Standards (NAAQS and AAQS), (2) radionuclides and other Hazardous Air Pollutants (HAPs) regulated under the National Emissions Standards for Hazardous Air Pollutants (NESHAP), and (3) other types of toxic air pollutants (TAPs), which are regulated by some states, and (4) ozone depleting substances (ODS), such as chlorofluorocarbons (CFCs) and halons. The analysis evaluated air quality impacts qualitatively from stationary-sources and transportation sources for the first three classes of pollutants. ODS impacts are discussed qualitatively but their emissions were not quantified.

Major Types of Air Pollutants

Criteria Air Pollutants: *carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), lead (Pb), ozone (O_3), and particulate matter less than 10 microns in diameter (PM_{10})*

Hazardous Air Pollutants: *189 hazardous substances (including radionuclides) whose emissions are regulated by the Clean Air Act*

Toxic Air Pollutants: *Other toxic compounds regulated by EPA and state or local governments*

Ozone Depleting Substances: *Certain man-made halocarbons (including chlorofluorocarbons [CFCs], halons, carbon tetrachloride, and 1,1,1-trichloroethane) whose manufacture and use is regulated by EPA under the Clean Air Act.*

Criteria pollutants consist of the six substances regulated by EPA (40 CFR 50) for which NAAQS have been established under the Clean Air Act (CAA): CO, SO_2, NO_2, Pb, O_3, and PM_{10}. They are regulated both in terms of annual production in tons per year and in terms of ambient concentrations emanating from point and mobile sources. Unlike the other five criteria pollutants ozone is not a direct emission, but is formed in the atmosphere through a complex reaction of ozone precursor pollutants, sunlight, and temperature. ***Ozone precursor*** pollutants include nitrogen oxides (NO_x) and non-methane hydrocarbons (NMHCs). The analysis of ozone impacts was done by evaluating NO_x and VOCs emissions as criteria pollutants.

Hazardous air pollutants include 189 substances listed in Section 112 of the Clean Air Act of 1990 (42 USC 7401 *et seq.*), as amended through May 1992, whose emissions standards are regulated by the NESHAP in 40 CFR 61. In particular, HAPs include cancer-causing agents such as arsenic, benzene, carbon tetrachloride, and formaldehyde, as well as materials with non-cancer health hazards, such as fluoride, ammonia, and hydrochloric and sulfuric acids. EPA regulates radionuclides as a total annual dose limit (10 mrem/yr) from the air pathway under the NESHAP (40 CFR 61). ***Radionuclides*** are also regulated by the DOE (DOE, 1990; DOE, 1993b) as a total annual dose limit (100 mrem/yr).

Toxic air pollutants include cancer causing agents and compounds with non-cancer health hazards. These substances are regulated by the EPA and on a state or local basis, through allowable ambient standards or guidelines.

Ozone depleting substances are certain man-made halocarbons, including chlorofluorocarbons (CFCs), halons, carbon tetrachloride and 1,1,1-trichloroethane that react in the upper atmosphere to deplete the stratospheric ozone layer. These compounds are regulated through the CAA and by the Montreal Protocol on Substances that Deplete the Ozone Layer.

C.4.2.1.2 *Air Quality Impacts Analysis Procedures*

The air quality impacts analysis varied according to the pollutant classes and emissions sources expected to be important in each WM activity. Different analytical assumptions and techniques were used to best estimate the amounts of pollutants that could be emitted by each source. A summary of the air quality impacts that were evaluated in the PEIS is shown in Table C.4–2.

Table C.4-2. Impacts Evaluated for Air Quality

Impacts Assessed	Relevant Waste Types	Period of Analysis	Activities for Which Impacts are Assessed	Impacts Measure	Presentation of Results
Criteria Air Pollutant Emissions	All five waste types	Construction	Use of construction equipment and worker vehicles	Percent of tons/year standard	Tabular or text discussion
		Operations	Operation of incinerators, fuel use by all other WM facilities, worker vehicles, and waste shipment vehicles, where applicable	Percent of tons/year or concentration standard	Tabular or text discussion
Radionuclide Emissions	LLMW, LLW and TRUW[a]	Operations[c]	Operation of WM treatment, storage and disposal facilities, where applicable	Percent of dose standard	Tabular or text discussion
Hazardous and Toxic Air Pollutant Emissions	LLMW, TRU and HW[b]	Operations[c]	Operation of WM treatment, storage and disposal facilities, where applicable	Percent of concentration standard	Tabular or text discussion

[a] Emissions of radionuclides from HW and vitrified HLW are assumed to be negligible.
[b] Emissions of hazardous and toxic air pollutants from LLW and vitrified HLW are assumed to be negligible.
[c] Emissions assumed to be negligible during construction.

C.4.2.1.2.1 Analytical Approach for Different Pollutant Classes

For the air quality impacts analysis, stationary-source and area-source emissions were modeled and simple vehicular emissions factors were used to estimate mobile-source emissions for worker vehicle trips and waste transportation activities under each alternative.

C.4.2.1.2.1.1 Comparisons with Emission-based and Concentration-based Standards

The analysis of criteria pollutants varied according to the attainment status of a site's Air Quality Control Region for each pollutant. Annual emissions of the criteria pollutants from sites located in attainment

areas were estimated for comparison with the allowable increment levels established in the Prevention of Significant Deterioration (PSD) regulations (40 CFR 52.21). The PSD allowable increments, in tons per year, regulate stationary-source emissions and do not include mobile-source emissions such as those from automobiles. Criteria pollutant emissions from sites located in nonattainment areas were estimated for comparison with the General Conformity Guidelines de-minimis levels, in tons per year (40 CFR 93). The Conformity Guidelines regulate both stationary-source and mobile-source emissions.

Ambient concentrations of the criteria pollutants were estimated for comparison with the NAAQS and State AAQS. Concentrations of the HAPs (including radionuclides) and TAPs were estimated to compare with the EPA or State ambient allowable limits (AALs).

C.4.2.1.2.1.2 Stationary-Source Estimates from Human Health Risk Modeling

In the analysis of air quality impacts from stationary-source emissions, it was assumed that ambient concentrations of criteria, hazardous, and radioactive pollutants would increase according to estimated emissions from treatment, storage, and disposal facilities and that the most conservative estimates of those increases would be the estimates of concentrations that the maximally exposed individual (MEI) would be subject to in the human health risk assessment done for this PEIS (ORNL, 1995a). Therefore, the air quality impacts analysis of stationary-source emissions used data on emissions, airborne transport and fate, and MEI doses assembled for the human health risk assessment to evaluate air quality effects. This is a conservative approach that will result in overestimating air quality impacts because the MEI doses from the health risk assessment include ingestion of farm products in addition to direct inhalation. The air quality impacts analysis used modeled estimates of local stationary-source ambient concentrations for hazardous and toxic air pollutants by waste type. Radionuclide data were taken directly from the off-site MEI doses estimated in the human health risk assessment.

C.4.2.1.2.1.3 Transportation Source Assumptions

In the air quality analysis, it was assumed that transportation sources (mobile-sources) may be an important source of criteria pollutant emissions in addition to those emanating from the facilities. Transportation sources were not expected to contribute significantly to hazardous (including radioactive)

and toxic airborne contaminants in routine operations. Therefore, for criteria pollutants only, the analysis estimated local transportation-source annual tonnage of criteria pollutants, intersite transportation annual tonnage of criteria pollutants, and a national annual tonnage of criteria pollutants from all activities proposed under each alternative.

C.4.2.1.2.2 Emissions Estimation Techniques

Details of the estimation methods for construction-phase and operations-phase air emissions are presented in this section.

C.4.2.1.2.2.1 Construction-Phase Air Emissions Estimates

Emissions due to construction activities were calculated using estimates the amount of fuel used by construction equipment, and by construction workers traveling to and from the work site.

Construction Equipment Fuel Use. Fuel use in gallons of liquid fuel for the construction of WM facilities (as described in Section C.3) were used to calculate annual emissions for the WM alternatives, in tons per year, for the criteria pollutants CO, NO_2, SO_2, PM_{10}, and ozone (as NO_x and VOC).

The fuel use values were divided by the WM alternative construction period (in years) to obtain an annual fuel usage in gallons. For the assessment of air emissions it was assumed that diesel fuel was used to operate construction equipment at the site. Emission rate factors, in pounds per gallon of fuel consumed, were obtained from *Compilation of Air Pollutant Emission Factors, Volume II, Mobile Sources*, also known as AP-42 (EPA, 1985a). The gallons of fuel used were multiplied by the pounds of pollutant per gallon consumed to obtain the annual emissions in pounds per year. This amount was divided by 2,000 pounds per ton to obtain the annual tons emitted for each of the criteria pollutants.

Worker Vehicle Fuel Use. The total number of FTEs for the construction period (as described in Section C.3) was divided by the construction period in years to obtain the total number of annual workers for each site and alternative combination. In order to provide an upper bound on air quality impacts, it was

assumed that each construction worker travels to and from the construction site in a single vehicle, and that no employees carpool.

Vehicle emissions rates for the worker vehicle trips were obtained by running the EPA-approved vehicle emissions models Mobile5a (EPA, 1994a) and PART5 (EPA, 1994b). Emissions from the Mobile5a model were calculated in grams of pollutant emitted per vehicle mile traveled (VMT) for the pollutants CO, NO_2, and VOC. The PART5 model calculated PM_{10} emissions from vehicle exhaust in grams of pollutant emitted per VMT. For local impacts, it was assumed that the worker vehicles traveled 20 miles to and from work or 40 miles round trip each day. The total number of worker trips per day was multiplied by 40 miles per day and then by 240 working days per year to obtain the VMT per year. The annual VMT was then multiplied by the Mobile5a and PART5 emission rate factors in grams of pollutant per VMT to obtain the total number of grams emitted per year for the criteria pollutants CO, NO_2, VOC, and PM_{10}. The annual emissions in grams were then multiplied by 0.0022 pounds per gram and divided by 2,000 pounds per ton to obtain the annual emissions for worker vehicles in tons per year.

C.4.2.1.2.2.2 Operations-Phase Air Emissions Estimates

The impacts to air quality from the operation and maintenance of WM treatment, storage, and disposal facilities were determined by calculating the emissions from facility fuel use, incineration of waste, transportation of waste, and worker vehicle trips to and from the sites.

Waste Management Fuel Use. Facility fuel use values during the operation period of WM facilities were supplied in pounds of natural gas and gallons of liquid fuel. These fuel use values were used to calculate annual emissions for the WM Alternative, in tons per year, for the six criteria pollutants at each site under each alternative.

The fuel use values were divided by the WM alternative period (in years) to obtain an annual usage for both natural gas, in pounds, and liquid fuel, in gallons. It was assumed that both classes of fuel were burned in an industrial boiler to produce heat and steam for the WM facilities. Emission characteristics for the burning of No. 4 fuel oil, with an assumed sulfur content of 1%, were used to represent the liquid fuel.

Emission rate factors in pounds per million cubic feet for natural gas and pounds per 1,000 gallons of liquid fuel for No. 4 fuel oil were obtained from the *Compilation of Air Pollutant Emission Factors, Volume I Stationary Sources* (AP-42) (EPA, 1985b). The estimates of natural gas use, in pounds, were divided by a natural gas density of 0.0448 pounds per cubic foot to obtain a total number of cubic feet. The total number of cubic feet was then divided by 1 million to obtain the number of million cubic feet used. The number of million cubic feet used was multiplied by the pollutant emission factor, in pounds per million cubic feet, to obtain the amount of pollutant emitted in pounds per year. The total annual pounds emitted was divided by 2,000 pounds per ton to obtain the annual tons emitted for each of the six criteria pollutants.

Direct Emissions from Incinerators: Criteria Pollutants. Criteria pollutant emissions from incineration of waste were calculated for annual emissions, in tons per year, and in parts per million or micrograms per cubic meter. The annual emissions were calculated using waste volumes for treatment and pollutant emission rate data. The emission rate data were supplied for each of the six criteria pollutants in grams of pollutant emitted per kilogram of waste incinerated. The kilograms of waste incinerated per year were multiplied by the grams of pollutant per kilogram of waste treated to obtain the total amount of pollutants emitted in grams per year. The total grams emitted per year were multiplied by 0.0022 pounds per gram and then divided by 2,000 pounds per ton to obtain the total amount of pollutant emissions in tons per year.

Ambient concentrations of the criteria pollutant emissions were calculated by obtaining the annual emissions in grams per year, as described above, and dividing by the period of incineration operation, in seconds per year, to obtain a pollutant emission rate in grams per second. The annual emission rate in grams per second was multiplied by the highest off-site receptor concentration obtained from dispersion modeling. The dispersion model used was the EPA-approved Industrial Source Complex Long Term Revision 2 (ISC2) dispersion model (EPA, 1987). The model was run using an emission rate of one gram per second to produce annual receptor concentration values in micrograms per cubic meter per one gram per second ($\mu g/m^3/g/sec$). To obtain a new concentration value for a different emission rate, the normalized concentration was multiplied by the new emission rate; the new concentration value was in micrograms per cubic meter ($\mu g/m^3$). The new annual concentration was divided by averaging period persistence factors, obtained from the EPA document *Air/Superfund National Technical Guidance Study Series, Screening Procedures for Estimating the Air Impacts of Incineration at Superfund Sites* (EPA,

1992a) to produce short-term concentrations for different averaging periods. These concentration values were compared to the NAAQS or State AAQS pollutant specific averaging periods as appropriate.

Direct Emissions from Incinerators: Hazardous and Toxic Air Pollutants. Annual exposure concentrations of HAPs and TAPs, in $\mu g/m^3$, to the off-site MEI were obtained from the human health risk assessment (Appendix D). For comparison of the HAPs and TAPs concentrations to State or EPA AALs, the concentrations were multiplied by the appropriate AAL averaging period persistence factor. The HAPs concentrations were divided by the AALs to obtain the percentage of the HAPs to the AALs.

The following four AAL guidelines were used; State, EPA Region III, EPA Region IX, and EPA long-term action level. The order in which the different guidelines were applied was as follows: the state guideline was applied in all cases where the state had established guidelines; for those states with no adopted guidelines and located in either EPA Region III or IX, the EPA Region guidelines were applied; for those states with no guidelines which were not located in either EPA Region III or IX, the EPA long-term action levels were applied.

Worker Vehicle Fuel Use. The total number of FTE employees for the waste treatment period was divided by the treatment period in years to obtain the total annual number of workers for each site and WM alternative. It was assumed (with the exception of Hanford) that each worker travels to and from the site in a single vehicle each day. For Hanford, the worker trips were adjusted to account for the percentage of employees who participate in ride-sharing programs. A worker trip reduction value of approximately 19% was obtained from the *FY 1993 Annual Report on In-house Energy Management* (Kaiser Engineers Hanford and Westinghouse Hanford Company, 1994), and applied to all Hanford worker trip numbers.

Vehicle emissions rates for the worker vehicle trips were obtained by running the EPA-approved vehicle emissions models Mobile5a and PART5. Emissions from the Mobile5a model are calculated in grams of pollutant exhaust per VMT for the pollutants CO, NO_2, and VOC. The PART5 model calculated PM_{10} emissions from vehicle exhaust in grams of pollutant emitted per VMT.

For local impacts, it was assumed that the worker vehicle traveled 20 miles to and from work, or a round trip distance of 40 miles per day. The total number of worker trips per day was multiplied by 40 miles per day and then by 240 working days per year to obtain the total VMT per year. The annual VMT was

multiplied by the Mobile5a and PART5 emission factors in grams of pollutant per VMT to obtain the total number of grams emitted per year for the criteria pollutants CO, NO_2, VOC, and PM_{10}. The annual emissions in grams were multiplied by 0.0022 pounds per gram and then divided by 2,000 pounds per ton to obtain the annual emissions for worker vehicle trips in tons per year.

Indirect Emissions from Waste Shipments. Air emissions from shipment of waste from site to site (intersite), and to commercial waste handlers for HW, were calculated for local and national impacts. Local impacts were calculated for the site region of influence (ROI) (defined as a 50-mile radius), while intersite impacts were calculated based on the mileage traveled between sites, excluding the emissions calculated locally in the 50-mile radius. The intersite shipment emissions represent the contributions to regional or national levels of the criteria air pollutants, which are not accounted for in the site analysis.

The total number of waste shipments entering and leaving each WM site for the treatment period was obtained from ANL. The number of shipments per treatment period was then divided by the length of the treatment period in years to obtain the total number of shipments to and from the site on an annual basis.

Vehicle emissions rates for the truck shipments were obtained by running the EPA approved vehicle emissions models Mobile5a and PART5 as described above.

For local impacts the shipment miles were calculated using a travel distance of 50 miles to and from the site, or a round trip of 100 miles. The annual shipment numbers were multiplied by 100 miles to obtain the total annual VMT. The annual VMT was then multiplied by the Mobile5a and PART5 emission rate factors, in grams of pollutant per VMT, to obtain the total annual number of grams emitted for the criteria pollutants CO, NO_2, VOC, and PM_{10}. The annual emissions in grams were then multiplied by 0.0022 pounds per gram and then divided by 2,000 pounds per ton to obtain the annual emissions for shipment by truck in tons per year.

Radiation Dose Estimates. Total radiation dose values, in rem, were obtained from the human health risk assessment for the MEI at an off-site location. The total dose values in rem were multiplied by 1,000 to obtain the dose in millirem (mrem). The dose was then divided by the period of operation (10 or 20 years) and compared to the NESHAP dose standard of 10 mrem per year.

C.4.2.1.3 *Air Quality Impacts Evaluation*

In general, air quality impacts were evaluated by comparing estimated emissions and concentrations to 10% and 100% of Federal or State standards.

C.4.2.1.3.1 Impacts Evaluation for Criteria Pollutants

Criteria pollutant effects were assessed based on the air quality *attainment status* of each site's air quality control region (AQCR), for each of the six criteria pollutants. In general, the site's applicable AQCR is in attainment for a particular criteria pollutant if monitored ambient levels are below the NAAQS for that pollutant. The site's applicable AQCR is a nonattainment area for a particular criteria pollutant if ambient levels equal or exceed the NAAQS for that pollutant. The attainment status of the DOE sites for the NAAQS criteria pollutants are listed in Table C.4–3. Table C.4–4 explains the nonattainment status designations.

C.4.2.1.3.1.1 Impacts for Installations in Attainment Regions

Any predicted increases to ambient concentration levels in areas designated as attainment by the EPA were compared to the NAAQS. If the estimated ambient concentrations exceeded the NAAQS then that WM alternative and the affected area were noted in the PEIS.

The annual criteria emissions, in tons per year, were compared to the allowable increase levels specified in 40 CFR 52.21, Regulations for the Prevention of Significant Deterioration (PSD) of Ambient Air Quality. PSD regulations are applicable in those 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. If the estimated annual emissions exceeded the allowable PSD increments then that WM alternative and the affected area were noted in the PEIS. PSD increments account for all stationary-source emissions that can be reasonably attributed to the action but do not account for emission from mobile sources. PSD increments for attainment areas are listed in Table C.4–5.

Table C.4-3. Site Criteria Pollutant Attainment Designation

Site	State	NAAQS Attainment Status					
		CO	NO_2	O_3	Pb	PM_{10}	SO_2
ANL-E	IL	A	A	S-17	A	MOD	A
BNL	NY	A	A	S-17	A	A	A
FEMP	OH	A	A	MOD	A	A	A
Hanford	WA	A	A	A	A	A	A
INEL	ID	A	A	A	A	A	A
LANL	NM	A	A	A	A	A	A
LLNL	CA	MOD-1	A	MOD	A	A	A
NTS	NV	MOD-2	A	A	A	MOD	A
ORR	TN	A	A	A	A	A	A
PGDP	KY	A	A	MAR	A	A	A
PORTS	OH	A	A	A	A	A	A
Pantex	TX	A	A	A	A	A	A
RFETS	CO	MOD-2	A	TRANS	A	MOD	A
SNL-NM	NM	MOD-1	A	A	A	A	A
SRS	SC	A	A	A	A	A	A
WIPP	NM	A	A	A	A	A	A
WVDP	NY	A	A	A	A	A	A

CO = carbon monoxide; NO_2 = nitrogen dioxide; O_3 = ozone; Pb = lead; PM_{10} = particulate matter <10 microns; SO_2 = sulfur dioxide. A = Attainment, Nonattainment codes: S-17 = Severe-17; MOD-2 = Moderate-2; MOD-1 = Moderate-1; MOD = Moderate; MAR = Marginal; TRANS = Transitional.

Source: 40 CFR 81, Subpart C: Section 107 *Attainment Status Designations*.

Table C.4–4. Nonattainment Status Definitions

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.4–3 are shown.

Table C.4–5. PSD Increments for Criteria Pollutant Emissions in Attainment Areas

Pollutant	Tons/Year
Carbon Monoxide (CO)	100
Nitrogen Dioxide (NO_2)	40
Ozone (O_3)	40
Lead (Pb)	0.6
Particulate (TSP)	25
Particulate (PM_{10})	15
Sulfur Dioxide (SO_2)	40

Source: 40 CFR 52.21.

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 guidelines of the Clean Air Act General Conformity Rule (GCR) (40 CFR 93) in determining the conformity of the action to Section 176(c) of the Clean Air Act 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 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.4-6.

Table C.4-6. General Conformity Rule de minimis Levels for Nonattainment Areas

Pollutant & 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.4.2.1.3.2 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 non-criteria 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.

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 (ODS)

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 chlorofluorocarbons [CFCs], halons, carbon tetrachloride, and methyl chloroform), react in the upper atmosphere to deplete the stratospheric ozone layer.

In response to this awareness, the U.S. 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 CFCs at 1986 levels and for CFCs to be reduced by 50% by 1998.

The Clean Air Act (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 21, 1993: *Reduction*

of 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, 1995). 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 are considered to be acceptable. 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 National Pollutant Discharge Elimination System 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 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 the current source, onsite surface and groundwater resources would not be affected by water withdrawals at Rocky Flats Environmental Technology Site (RFETS), Sandia National Laboratory-New Mexico (SNL-NM), and Waste Isolation Pilot Plant (WIPP). Because groundwater is used as the current source, surface water resources would not be affected by water withdrawals at Argonne National Laboratory–East (ANL-E), Brookhaven National Laboratory (BNL), Fernald Environmental Management Project (FEMP), INEL, Los Alamos National Laboratory (LANL), LLNL Site-300, Nevada Test Site (NTS), Pantex Plant, Portsmouth Gaseous Diffusion Plant (Ports), and SRS. Because surface water is the current source, groundwater resources would not be affected by 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) Lawrence Livermore National Laboratory (LLNL)–Site 300; and Savannah River Site (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, would be treated, and then discharged to existing process or sanitary treatment plants, as appropriate. After the additional treatment, wastewater would be discharged from these plants in compliance with all NPDES and industrial wastewater discharge permits.

- 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 wastewaters are not discharged 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 would not 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. Therefore, the impacts analysis of contaminated groundwater bound the impacts of contaminated surface water.

- 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 are not likely 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.

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. 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. Therefore, the requirements of Executive Order 11988 (Floodplain Management)

and 10 CFR 1022 (Compliance with Floodplain/Wetland Environmental Review Requirements) are satisfied, and a floodplain and wetland assessment is not required in the PEIS. Compliance with floodplain and wetland review requirements would be examined in detail when specific locations are proposed in site-specific or project-level NEPA documents.

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 site-specific or project-level 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 evaluated 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. 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 evaluated in site-specific or project-level NEPA documents if necessary.

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 non-hazardous 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 evaluated in site-specific or project-level NEPA documents.

Impacts from Process Wastewater Discharges

Process wastewater (aqueous waste) is wastewater potentially contaminated by hazardous or radioactive constituents during treatment, storage or disposal activities. Process wastewaters from waste treatment facilities would be discharged to existing wastewater treatment facilities, where possible. After treatment, wastewaters would be recycled or discharged from these plants in compliance with site-specific DOE, NPDES, or industrial wastewater discharge permit limits.

The aqueous wastewaters that are currently being managed at the sites are not part of the WM PEIS. The WM PEIS includes only those aqueous wastes generated by the facilities analyzed as part of the PEIS alternatives. These WM facilities were assumed to be very efficient in water use. Process wastewater would be treated and recycled to the extent practicable with little liquid effluent discharge. Therefore there is little process wastewater that would be discharged to surface waters after treatment. Since process wastewater treatment would continue at all the sites where it presently occurs, and the volumes of process wastewater treated at each site would vary only slightly between alternatives. Therefore, the effects of process waste treatment on surface and groundwater quality are already accounted for in the affected environment section. 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 site-specific or project-level NEPA documents.

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 evaluated in detail in site-specific or project-level NEPA documents.

Impacts of Water Withdrawals on the Movement of Groundwater Contamination Plumes

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 evaluated in detail in site-specific or project-level NEPA documents.

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.

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.

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 clean-up would occur, long-term impacts to water quality are unlikely.

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.4-7.

First, current conditions at the sites were summarized from data in the Affected Environment Technical Report. Table C.4-8 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 Appendix C, 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.4–7. 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: – by personnel – for concrete – 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: – by personnel – 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

Table C.4-8. 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	City of DuPage Municipal Sewer System, Sawmill Creek & Des Plains River	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	NA
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	NA
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

[a] Data from "Affected Environment for the Waste Management Programmatic Environmental Impact Statement Department of Energy Sites"(M/B, 1995b). No Sites have Federally designated Wild & Scenic Rivers in the ROI, although the Hanford Reach of the Columbia River is being considered for inclusion. 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.
[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.

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

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 400%.

As shown in Table C.4–9, 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). Although not directly applicable to groundwater quality, these criteria are commonly used as ARARs to determine appropriate levels for groundwater cleanup. Since these criteria adequately protect human heath, then groundwater contamination at or below these levels is normally considered to be acceptable. 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.

Table C.4–9. Water Quality Comparison Criteria[a]

Constituent	EPA Drinking Water Regulations			DOE Derived Concentration Guides for Drinking Water[f]	EPA Quality Criteria for Fresh Water[g]	
	MCL[b]	SMCL[d]	Proposed MCL[e]		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			3200	2800		
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 c				0.082	0.0032
Mercury	0.002				0.0024	0.000012
Methylene Chloride	0.005					
Neptunium-237			7.06	1.2		
Nickel-59			27000	28000		
Nickel-63			9910	12000		

Table C.4-9. Water Quality Comparison Criteria[a]—Continued

Constituent	EPA Drinking Water Regulations			DOE Derived Concentration Guides for Drinking Water[f]	EPA Quality Criteria for Fresh Water[g]	
	MCL[b]	SMCL[d]	Proposed MCL[e]		Acute	Chronic
Palladium-107			36600	40000		
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 c		20	4		
Samarium-151			14100	16000		
Selenium	0.05				0.26	0.035
Selenium-79				800		
Silver		0.1			0.0041	0.00012
Strontium-90	8		42	40		
Technetium-99			3790	4000		
Thorium-229			49.3	1.6		
Thorium-230			79.2	12		
Thorium-232			88	2		
Tin-126			293	320		
Uranium-233			13.8	20		
Uranium-234			13.9	20		
Uranium-235			14.5	24		
Uranium-236			14.7	20		
Uranium-238			14.6	24		
Zirconium-93			5090	3600		

[a] Chemicals in mg/L. Radionuclides in pCi/L. MCL = maximum contaminant level. SMCL = secondary maximum contaminant level. Comparison criteria for 1,2,2-trichloro-1,1-trifluroethane and acetone were not found.
[b] Source: 40 CFR 141, *National Primary Drinking Water Regulations*, and EPA, 1991, *National Primary Drinking Water Regulations, Synthetic Organic Chemicals and Inorganic Chemicals; Final Rule*, 40 CFR 141 and 142, 57 FR 31776.
[c] Action level.
[d] Source: 40 CFR 143, *National Secondary Drinking Water Regulations*. SMCLs based on taste and odor effects.
[e] Source: EPA, 1991. *National Primary Drinking Water Regulations; Radionuclides, notice of proposed rulemaking*, 56 FR 33050, July 18, 1991. Concentration based on 4 mrem/year dose. Alpha emitters based on lifetime incidence risk of 1×10^{-4}
[f] Source: DOE Order 5400.5 (DOE, 1990), *Radiation Protection of the Public and the Environment*, June 5, 1990. Concentration based on 4 mrem/year effective dose equivalent.
[g] Source: EPA, 1986. *Quality Criteria for Water, 1986*, EPA 440/5-86-001, Office of Water Regulations and Standards, Washington, DC.

The EPA proposed maximum contaminant levels for radionuclides in drinking water (EPA, 1991) 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.

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 excluded from disposal would then become "special case wastes" that 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.

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; and
- accidental releases of transported wastes.

Table C.4–10 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 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.

Table C.4-10. 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				
Non-sensitive 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

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.3.1 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 10-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.

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).

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 (HI's) 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 hazard index (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 on Affected Environment chapter 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 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 foodchains. Foodchain exposure would produce internal exposures for benthic organisms and for fish or other organisms that feed on them.

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 Argonne National Laboratory as inputs to aquatic environmental fate models to estimate maximum credible radiological releases for transportation accidents involving HLW, LLW, and C-H and R-H 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, 1995).

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).

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.

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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.4–11). 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.4–11. 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 RCRA (42 USC 6901 *et seq.*) and NEPA (42 USC 4231 *et seq.*), for monitoring, and for shielding.

The specific project expenditure categories, as described in Section C.3.3, 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 Nitzche, 1994).

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 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.

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.4–12 and C.4–13.

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.

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 sold as a final good to the ultimate consumer.

- There are no available baseline measures of output available at the regional level. The model used to determine impacts provides a change in output given a change in initial expenditures, but there is no data available to compute a percent change in the baseline output.

Table C.4-12. Baseline Employment Data

Site	County/City	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%
BAPL	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%
FNAL	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%

Table C.4-12. Baseline Employment Data—Continued

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
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%
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%
HANF	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%
	Schohanie (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%

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Table C.4-12. Baseline Employment Data—Continued

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
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%
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%
MSP	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 (	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 (	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%

Table C.4-12. Baseline Employment Data—Continued

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
ORR	Anderson (TN)	20,457	24,385	30,785	32,310	39,083	91.0%
	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%
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 Harbor	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%
PIN	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%
Portsmouth	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 Sound	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%

Table C.4-12. Baseline Employment Data—Continued

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
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%
RFP	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%
SNLA	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%
UMo	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%
WSSRAP	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%
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%

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

Table C.4-13. Baseline Personal Income

TOTAL PERSONAL INCOME (In $MM)

Site	County/City	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%
BAPL	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%
FNAL	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%

Table C.4-13. Baseline Personal Income—Continued

TOTAL PERSONAL INCOME (in $MM)

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
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%
HANF	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%
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%
	Schohane (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%

Table C.4-13. Baseline Personal Income—Continued

TOTAL PERSONAL INCOME (in $MM)

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
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	5,835.3	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%
		4,669.1	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 Island	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%
MSP	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%
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	186.0	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)	295.6	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%

Table C.4-13. Baseline Personal Income—Continued

TOTAL PERSONAL INCOME (in $MM)

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
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 Harbor	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%
PIN	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%
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%
Portsmouth	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 Sound	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%

Table C.4-13. Baseline Personal Income—Continued

TOTAL PERSONAL INCOME (In $MM)

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
FMI	Ashtabula (OH)	347.8	526.1	875.2	1,102.7	1,337.9	284.7%
	Geauga (OH)	256.8	415.1	826.7	1,184.4	1,688.0	557.4%
	Lake (OH)	823.6	1,276.0	2,270.5	3,096.8	4,249.0	416.9%
	Trumbull (OH)	935.6	1,494.9	2,400.7	2,937.9	3,673.8	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%
RFP	Adams (CO)	659.4	1,151.3	2,288.6	3,461.4	4,274.6	548.2%
	Arapahoe (CO)	808.9	1,704.1	3,828.3	6,667.0	8,650.0	969.2%
	Boulder (CO)	556.8	1,005.4	2,125.7	3,479.2	4,643.5	769.6%
	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%
SNLA	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%
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%
UMo	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	288.7	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%
WSSRAP	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	608.0	1,454.9	2,610.8	4,036.8	982.5%
	St. Louis (MO)	4,685.5	7,329.9	11,901.7	17,713.2	24,097.6	393.2%
	Madison (IL)	996.1	1,470.2	2,459.0	3,350.6	4,487.0	350.9%
	Monroe (IL)	66.2	109.7	212.4	307.2	466.9	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%

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 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 BEA's 1987 *U.S. Use and Make Tables* 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

$MAKE_N$ = 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 are output for industry "i" and total industry output in the region
X^N_i and X^N are 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 are national income for industry "i" and total income for the Nation
Y^R_i and Y^R are 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"

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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.

There is an advantage in using individual multipliers because of 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 taken from the analysis described

in Section C.3.3. 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.4–14 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.

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.

Table C.4–14. Duration in Years of WM Activity Phases Assumed for Waste Type Economic Analysis

Waste Type	Construction Phase	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	34
HW	4	12	10

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.4–15.

Table C.4–15. 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

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.4–16 and Table C.4–17, respectively.

Table C.4–16. 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
BAPL	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
FNAL	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 Island	2.0097511	0.2841494	26.5
MSP	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 Harbor	1.8166110	0.2560974	24.3
PIN	1.9382666	0.2750944	25.8
PORTS	1.7395320	0.2644895	24.8
Portsmouth	2.0104574	0.2857046	26.3
PPPL	2.0962324	0.2967151	26.8
Puget Sound	1.9194054	0.2736098	25.3
RMI	1.8073449	0.2559203	23.4
RFETS	1.9088693	0.2832914	25.2
SNLA	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
WSSRAP	2.1302335	0.3014761	27.3
WVDP	2.1326031	0.3170268	27.8
NATIONAL	3.0829564	0.8324667	36.8

Notes:

(1) The total dollar change in output that occurs across all industries for each additional dollar of output delivered to final demand.

(2) The total dollar change in earnings of households employed by all industries for each additional dollar of output delivered to final demand.

(3) The total change in number of jobs in all industries for each additional 1 million dollars of output delivered to final demand in a given year.

Table C.4-17. Multipliers' Coefficient of Variance

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
BAPL	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
FNAL	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 Island	0.1336816	0.3163528	0.6208246
MSP	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 Harbor	0.1267270	0.3324984	0.6697828
PIN	0.1146860	0.3179148	0.6247028
PORTS	0.1408416	0.5007350	0.7359551
Portsmouth	0.1414415	0.3262595	0.5881818
PPPL	0.1343447	0.3116302	0.5635358
Puget Sound	0.1342005	0.3296160	0.6086124
RMI	0.1327751	0.3383731	0.6790840
RFETS	0.1261521	0.4754906	0.6146155
SNLA	0.1197497	0.4900238	0.6760818
SRS	0.1370186	0.4650688	0.7017991
SLAC	0.1079955	0.3308188	0.6862206
UMo	0.1305158	0.3448562	0.7495700
WIPP	0.1205319	0.5070867	0.7579089
WSSRAP	0.1401402	0.3130342	0.5595690
WVDP	0.1362926	0.4282287	0.5648346
NATIONAL	0.1816865	0.2830192	0.3542612

Note: The coefficient of variance is equal to the standard deviation of the mean multiplier divided by the mean.

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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; 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.

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 were those described in Section C.3.3 of this appendix. They 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 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 the Affected Environment for the DOE Sites Considered in the WM PEIS (M/B SR-01). 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; Cantor, 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.

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 (Cantor, 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).

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

- The percentage of construction jobs filled by in-migrants would 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.4–18 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.

Table C.4–18. 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	HS, NTS
60	INEL, LANL, PGDP, Pantex, Ports, SRS, WIPP

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. 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 to minority and low-income populations. DOE identified and mapped the distribution of minority and low-income populations at 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, both normal facility operations and accident conditions were examined, with accident scenarios evaluated in terms of the risk to the public. Likewise, the examination of transportation included both routine transportation effects and the effects of potential accidents for truck and rail transportation of the waste types. Special exposure pathways were evaluated with respect to subsistence consumption of fish, game, or native plants.

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.

C.4.7.1.1 *Studies Supporting Environmental Justice Concerns*

A number of studies, particularly those by the United Church of Christ and the EPA Environmental Equity Workgroup, have indicated a positive correlation between the locations of minority and low-income communities and the location of potentially polluting facilities such as industrial plants and hazardous waste facilities (United Church of Christ, 1987; EPA, 1992b).

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The United Church of Christ study found that race was more strongly correlated to residence near a hazardous waste site than to income status (United Church of Christ, 1987). The EPA Environmental Equity Workgroup study found that:

- There are clear differences between racial groups in terms of diseases and death rates; however, there is a general lack of data on environmental health effects by race and income.

- People of color and low-income populations experience higher-than-average exposures to selected air pollutants, hazardous waste facilities, and contaminated fish.

- Data are not routinely collected on health risks posed by multiple industrial facilities, cumulative and synergistic effects, or multiple pathways of exposure.

- American Indians are a unique group with a special relationship to the Federal government and distinct environmental problems. Tribes generally lack physical infrastructure, institutions, trained personnel, and resources necessary to protect their members (EPA, 1994a; EPA, 1992b).

C.4.7.1.2 *Issuance of the Executive Order on Environmental Justice*

As a result of these and other studies, Executive Order 12898, ***Federal Actions to Address Environmental Justice in Minority and Low-Income Populations***, was developed by the administration during 1993 and became effective when signed on February 11, 1994 (Executive Order 12898). The Executive Order requires all Federal agencies to focus attention on the environmental and human health conditions in minority and low-income communities to promote nondiscrimination in federal programs substantially affecting human health and the environment. 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.

To accomplish these goals, the Executive Order focuses on the need for all Federal agencies to apply the substantive environmental requirements relating to the enforcement of existing laws in a non-discriminatory manner. The Executive Order also establishes a process for Federal agencies, individually and in concert, to implement these environmental justice requirements. To initiate this process, EPA has

convened an interagency Federal Working Group on Environmental Justice to provide guidance to Federal agencies, 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.

There are significant information-gathering requirements under the Executive Order. The extra dimension of minority and low-income populations is added to existing research, data collection, and analysis requirements to the extent practicable and appropriate. 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.

The public participation and information access requirements of the Executive Order are also significant. The public is encouraged to submit recommendations to Federal agencies relating to incorporation of environmental justice principles into agency programs or policies. Federal agencies must convey such recommendations to the Working Group. Whenever practicable and appropriate, agencies must translate relevant communication relating to human health or the environment for limited English speaking populations. Public documents, notices, and hearings relating to human health or the environment must be concise, understandable, and readily accessible to the public. In addition to other minority and low-income groups, Native Americans are specifically identified as requiring agency scrutiny under the requirements of the Executive Order.

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. 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 (DOC, 1992c; DOC, 1992d). 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, 1992e).

C.4.7.1.3 *Status of DOE Guidance on Environmental Justice*

The interagency Federal Working Group on Environmental Justice is directed to provide guidance to Federal agencies on criteria for identifying disproportionately high and adverse human health or environmental effects on minority populations and low-income populations. The Working Group is also directed to coordinate with each Federal agency to develop an environmental justice strategy, if a strategy is required by the proposed activities. At the time of this analysis, the Working Group had not issued final guidance on the approach to be used in analyzing environmental justice, as directed by the Executive Order. The Working Group has issued draft definitions of terms in the Draft Guidance for Federal Agencies on 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, DOE is developing internal guidance for the implementation of the Executive Order, which has not yet been finalized. Because both DOE and the Working Group are still in the process of developing guidance, the approach used in this analysis might depart somewhat from whatever guidance is eventually issued.

C.4.7.2 Approach to PEIS Consideration of Environmental Justice Impacts

For the environmental justice assessment, the following effects were evaluated for alternatives under each of the five waste types:

Disproportionately high and adverse human health effects: 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 human health effects occur when the risk or rate for a minority population or low-income population from exposure to an environmental hazard significantly exceeds the risk or rate to the general population and, where available, to another appropriate comparison group.

Disproportionately high and adverse environmental impacts: An adverse environmental impact is a deleterious environmental impact determined to be unacceptable or above generally accepted norms. A disproportionately high impact refers to an impact (or risk of an impact) to a low-income or minority community that significantly exceeds the same type of impact in the larger community.

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

Demographic information obtained from the U.S. Bureau of Census was used to identify minority and low-income populations in the zone of potential impact surrounding each of the sites under consideration. This zone is defined as a circle with origin at the site center and an 80-kilometer (50-mile) radius. This 80-kilometer (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 specify 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. Transportation impacts are assessed within 800 meters (0.5 miles) of transportation routes for incident-free transportation because impacts beyond this distance are expected to be negligible. For transportation accidents, an 80-kilometer (50-mile) radius was used.

Definitions

Definitions used to develop and map the community characteristics data are as follows:

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, with 4,000 persons being ideal. 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.

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. For the purposes of this analysis, a minority populations was defined as any census tract within the 50-mile zone of impact where minority individuals comprise 50% or more of the population. A ***low-income population*** was defined as a census tract with a median income to a family of four equal to or below the national poverty level of $12,674. Census tracts were included in the analysis if 50% of the area of the tract fell within the 80-kilometer (50-mile) radius..

Mapping Procedures

For each of the 17 major WM sites, demographic maps were prepared using 1990 census data available from the U.S. Bureau of the Census. Maps of the minority and low-income populations are shown in Appendix I. Figures I-1 through I-17 and Figures I-18 through I-34 illustrate census tract distributions for minority populations and low-income populations respectively for areas surrounding the 17 DOE sites being considered for the management of the five waste types. These maps are based on an analysis of 1990 United States Bureau of the Census Tiger Line files, which contain political boundaries and geographical features, and Summary Tape Files 3A (as processed by the U.S. Environmental Protection Agency), which contain demographic information (DOC, 1992c; DOC, 1992d; DOC, 1992e). Data were resolved to the census tract group level. 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. Native American tribal lands

within 50 miles of each site were also identified and mapped and are included in Appendix I, where applicable, with the minority distribution maps I-1 through I-17

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. The analysis focused on risks to the maximally-exposed individual (MEI) members of the offsite population at the sites and in the transportation corridors. The expectation was that the PEIS human health risk assessment findings would indicate that risks to the general population from WM actions at each site would be low. Therefore, only in instances where certain individuals identified as MEIs are at high risk would there be a potential for disproportionately high and adverse health risks to minority or low-income communities. If risks to MEIs were also low then no segment of the population would experience disproportionately high and adverse health risks including any minority or low-income populations.

The analysis also reviewed environmental impacts, focusing on such effects as air quality impacts that are likely to directly affect offsite populations. Special consideration was also given to the potential for effects on subsistence hunters and fishermen in terms of contamination of fish or game and in terms of reductions in game populations caused by vehicle collisions. As was the case with health risk, if environmental impacts in general were low then only in the instance of a specific impact being high at a particular site would there be a potential for disproportionately high and adverse impacts to minority or low-income groups. Where risks or environmental impacts were found to be significant, 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.4.8 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.4–19. Proposed increases in site employment under the various alternatives is compared to current site employment to determine possible impacts to transportation infrastructure.

Table C.4-19. 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
HS	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	643

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*

Native American resources refer to 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 regulations are specifically applicable to the protection of Native American resources including American Indian Religious Freedom Act of 1978 (42 USC 1996) and the Native American Graves Protection and Repatriation Act of 1990 (25 USC 3001 *et seq.*). 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.

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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 Part 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 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).

Chapter 4 identifies the extent to which installations have been surveyed for cultural resources and lists registered cultural properties. Chapters 6 through 10 display acreage requirements for treatment, storage, or disposal construction as estimates of the amount of land that may be disturbed at each site and may therefore require a cultural resource survey. Acreages are given by site and by alternative, and are totaled across sites as estimates of alternative-specific survey requirements. In general, the smaller the total acreage required, the lower the likelihood that National Register eligible properties will be affected by new facility construction. Thus, the waste management alternative that requires the smallest total land area at the individual sites would appear to be preferable from a cultural resources perspective. This may be partially offset by the greater acreages required at the fewer regional or the single centralized sites, although these sites are generally the much larger sites, which gives DOE a greater ability to locate the new waste management facilities so as to avoid affecting cultural resources.

Appendix C
References

CFR: Code of Federal Regulations: 10 CFR 1021 is read "Title 10 of the Code of Federal Regulations, Part 1021."

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Appendix D

Waste Management Facility Human Health Risk Estimates

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

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Acronyms and Abbreviations

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-LLMW	contact-handled low-level mixed waste
CH-TRUW	contact-handled transuranic waste
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

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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
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
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	most-exposed individual
MEL	most-exposed lifetime of the hypothetical farm family
MEPAS	Multimedia Environmental Pollutant Assessment System
NAS	National Academy of Science
NAS/NRC	National Academy of Sciences/National Research Council
NE	northeast

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
PNL	Pacific Northwest 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
RH-LLMW	remote-handled low-level mixed waste
RH-TRUW	remote-handled transuranic waste
RFETS	Rocky Flats Environmental Technology Site
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
U of Mo	University of Missouri at Columbia
WIPP	Waste Isolation Pilot Plant

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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)

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m^3	cubic meter(s)
mi	mile(s)
min	minute(s)
mph	miles per hour
mrem	milliroentgen equivalent man
N	north
nCi	nanocurie(s)
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)

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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, 1995e).

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.

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 installations 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, 1991b; ICRP, 1977, 1979, 1990) or developed specifically for the PEIS (ORNL, 1995a, 1995b, 1995c). While it is important to recognize the purpose and limitations of this assessment, the same assumptions and methodologies were applied uniformly to all installations. 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 installation 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 installation 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, 1995b, 1995c, 1995d, 1995e).

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).

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 installation 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 installation where they were generated.
- Regionalized: Wastes are consolidated for processing and/or disposal at regional installations.
- Centralized: Wastes are consolidated for processing and/or disposal at one or two installations.

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 installations. 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 installations.

Many DOE installations do not currently have facilities for waste management. In the alternatives evaluation, it was necessary to assume that these installations 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 installations currently storing waste. It did not include federal facilities planned for waste disposal such as Yucca Mountain because these installations will be addressed in site-specific NEPA documents (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 installation 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, 1995b, 1995c).

D.2.1 Characterizing the Environmental Setting

The first step in estimating risk is to collect information about the installation'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 installation. The environmental setting information used in the PEIS can be found in the ORNL installation 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 following receptor categories were selected (1) to represent the populations that would most likely be exposed to contaminants during waste management activities or (2) as worst-case receptors for the risk analysis:

- Offsite (general public) population: The offsite population within an 80-km (50-mi) radius of each installation.
- Noninvolved workers: Onsite employees not directly involved in an installation's waste handling activities.
- Most-exposed individual (MEI) of the offsite population.
- MEI of the noninvolved worker population.
- Waste management workers: Onsite employees working in an installation'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 installation were obtained from the 1990 U.S. census. The population and distribution of noninvolved workers at each installation were estimated based on installation records, site maps, and best judgment. Because of lack of information, it was necessary at some installations 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 installation and the location of each installation's MEIs can be found in the ORNL installation 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 worst-case risk 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 *installation* the MEI is one individual; however, for each *alternative* (in which the impacts from all relevant installations are considered together), the MEI is a composite of the worst radiological exposure at any of those installations, the worst chemical carcinogen exposure at any of the installations, and the worst noncarcinogenic chemical exposure.

The hypothetical farm family and hypothetical intruder represent two worst-case 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 installation).

Risks to the hypothetical onsite farm family are evaluated for 143 consecutive 70-year lifetimes (e.g., 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 futuren 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 et al., 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 most-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, et al., 1988]). The intruder scenario is intended to show the worst-case 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, pregnant or nursing women, or people who consume a large quantity of locally-grown produce or fish from local water sources. 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).

In deciding whether to explicitly consider one or more sensitive subpopulations in the PEIS risk evaluation, it was necessary to determine whether the presence of such subpopulations might affect the exposure parameters used in the study. Certain Native American populations, for example, might consume larger quantities of locally grown produce or fish from local water sources than the population as a whole; this might result in higher risks to these particular people. However, the consumption of fish was eliminated as an exposure route of concern for the PEIS because postulated surface water contamination was found to be minimal (see Section D.2.3.1). In addition, it was assumed that all food grown within 80 km of an installation remained in the area and that all members of the offsite population

have the same dietary habits and consumption rates. On this basis, groups that consume relatively large quantities of locally grown produce or fish from local water sources were not differentiated from other members of the offsite population in this evaluation.

Another issue not explicitly addressed in the human health risk analysis was that of environmental justice impacts. This issue, which involves the consideration of minority and low-income populations in policy-making where negative impacts are expected, is discussed in detail in Appendix C. Executive Order 12898 mandates adding the dimension of minority and low-income populations to research, data collection, and analysis to the extent practicable and appropriate. From the perspective of human health risk, there would be little reason to assess risks differently for minority or low-income populations unless dietary habits or other factors were to cause their exposure to be substantially different from that of the population as a whole. A more comprehensive analysis of environmental justice impacts would require detailed site-level information beyond the scope of this programmatic document.

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

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. The following table summarizes the results for uranium-238.

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-1	10 orders of magnitude
	300	5.3E-13	3.6E-4	9 orders of magnitude
	16,100	7.7E-15	9.5E-8	7 orders of magnitude
Clinch	10	3.4E-12	3.6E-4	8 orders of magnitude
	300	7.7E-11	2.4E-1	10 orders of magnitude
	16,100	1.0E-13	1.9E-7	6 orders of magnitude

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

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. 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.

Overland Runoff. Overland runoff involves an additional time delay and dilution factor with respect to direct deposition of contaminants on surface water. Since the latter case involves negligible contributions to risk, the former would pose even less of a contribution to risk. For this reason, the overland runoff pathway was not analyzed in the PEIS.

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**
Benzene	--	--	7.5E-19	8.7E-10	9 orders of magnitude
1,1,1-Trichloroethane	1.4E-14	7.8E-6	--	--	8 orders of magnitude

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

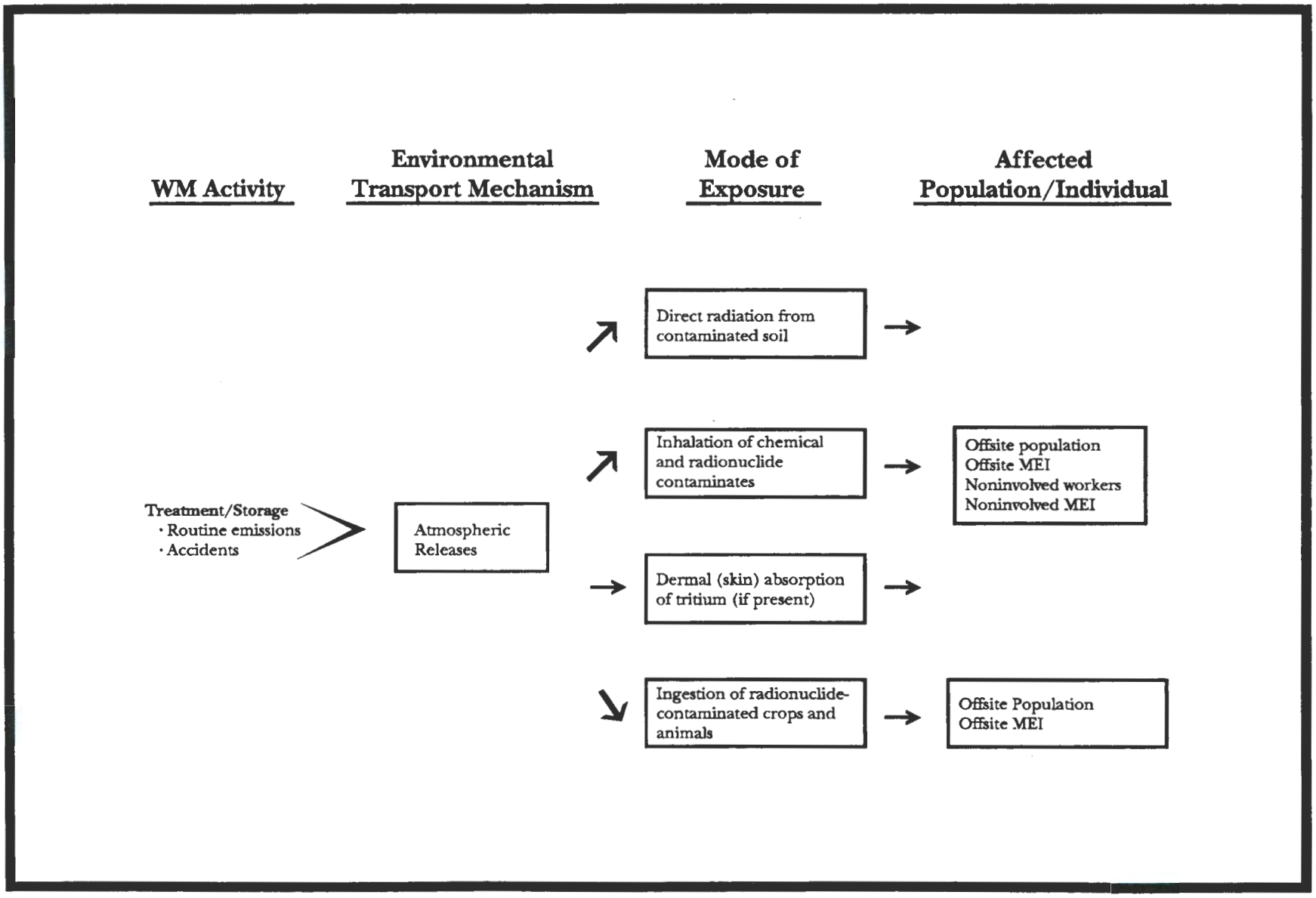
D.2.4 Identifying Likely Exposure Routes For Populations and Individuals

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, D.2-2, D.2-3, and D.2-4.

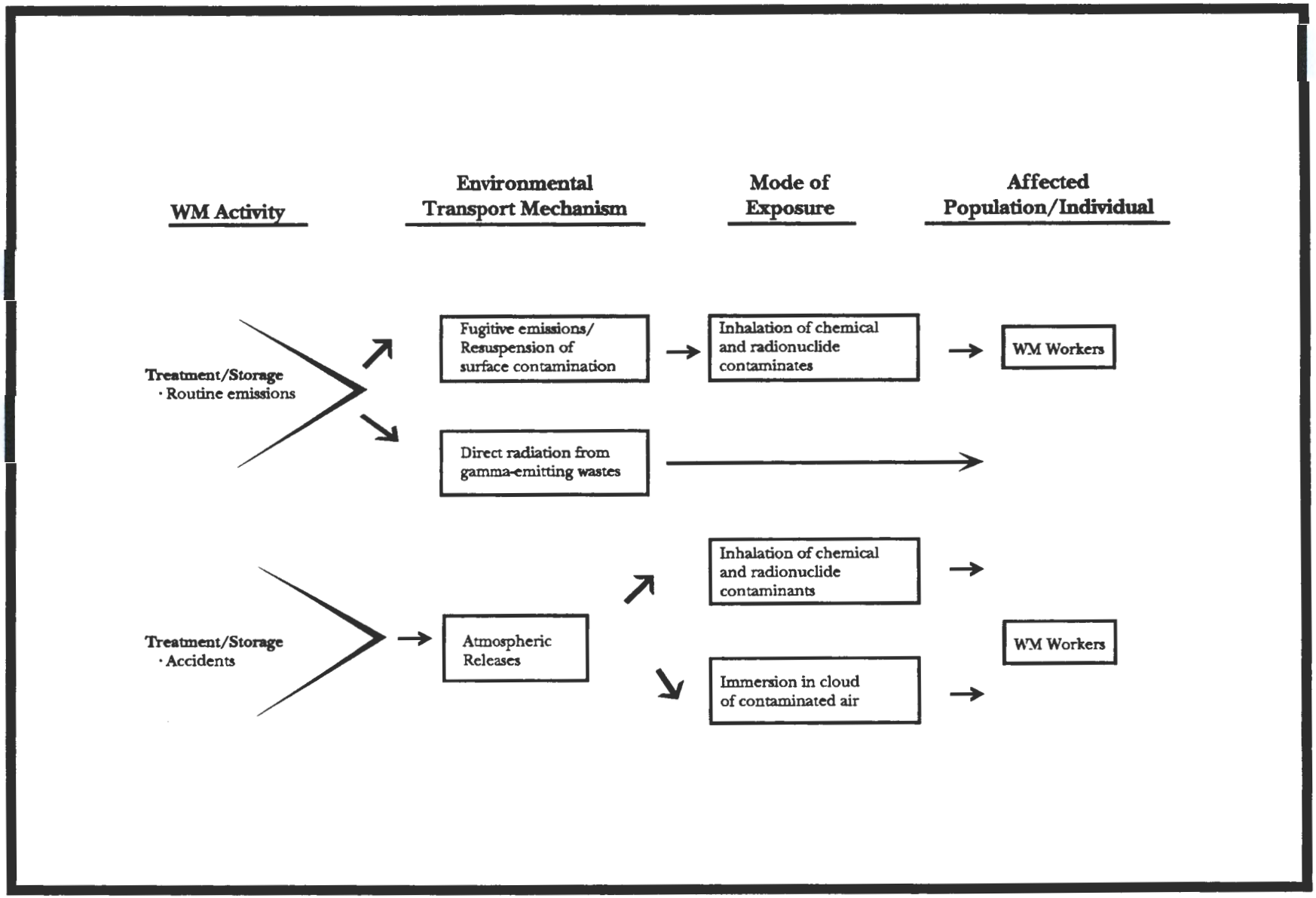
D.2.4.1 Offsite and Noninvolved Worker Population Exposure Routes

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.

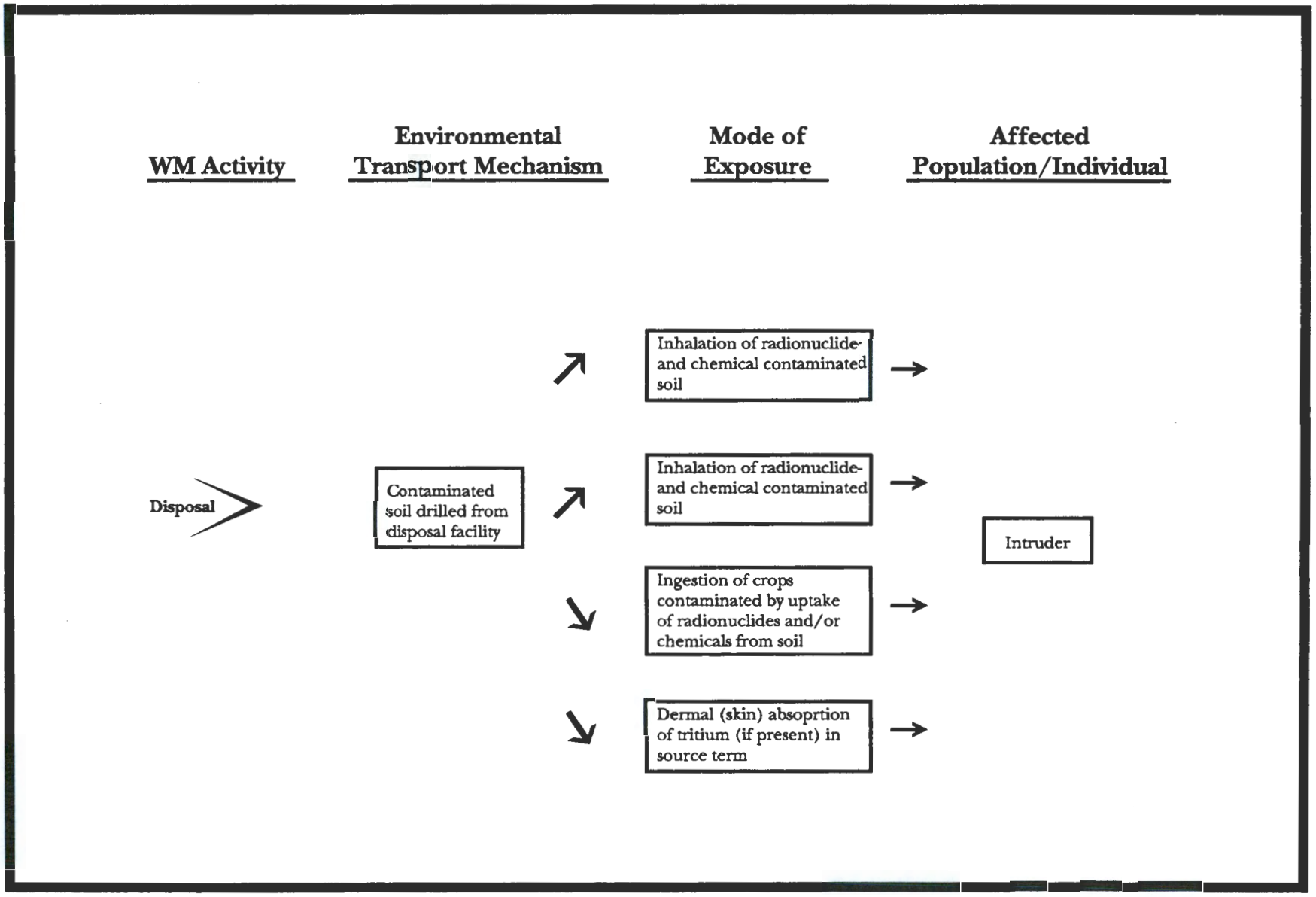
The offsite and noninvolved worker populations were evaluated for dermal exposure to tritium derived from tritiated water in the atmosphere. Both absorption through the skin and the lungs were taken into account; this combined rate of absorption was assumed to be 150% of the inhalation intake rate alone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



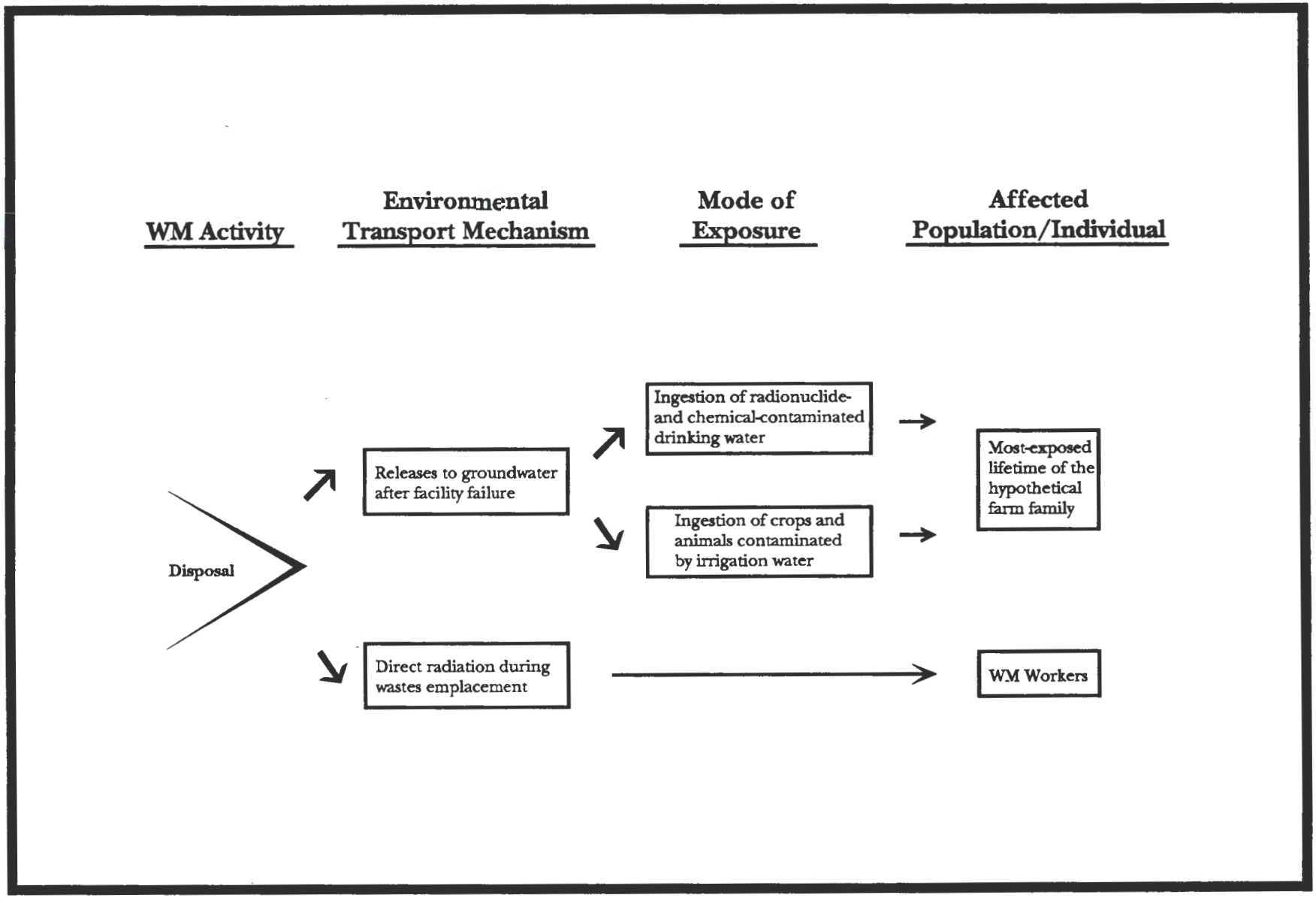
D.2–1. Exposure Routes for the Offsite and Noninvolved Worker Populations for Treatment and Storage Activities



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



D.2-3. Exposure Routes for the Intruder for Disposal Activities



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

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.

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 contaminated soil. 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 non-workers (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 installation, 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, 1995b).

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 and IRIS (for all receptors except waste management workers), and intake values for chemical carcinogens are multiplied by EPA cancer slope factors (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.

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/year), 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 installations; hence, the *relative* ranking of installations 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, 1995b, 1995c).

D.2.7.1 Calculating Exposures to the Offsite and Noninvolved Populations, the Hypothetical Farm Family, and the 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 worst-case 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, 1992) 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, and LLMW; 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 of Occupational Safety and Health. 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 installation'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 installation, 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 installation for a particular alternative, they are scaled up based on the waste inventory at that installation. To estimate exposures to the offsite and noninvolved populations, intruder, and farm family posed by a particular contaminant at the installation, 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 installation.

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.

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.

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

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

[a] 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.
[b] Includes weighting for severity of hereditary effects, but not for years of life lost should harm occur.

Source: ICRP, 1990.

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 Installation 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 the Offsite Population**—The unit dose of 0.0001 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 Installation X is 20 Ci/year:

$$0.0001 \text{ rem/Ci/year} \times 20 \text{ Ci/year} = 0.002 \text{ person-rem} \quad \textbf{(1)}$$

- **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 Installation 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 Installation X:

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

- **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 Installation X for the entire 20-year release period, the annual risk calculated in equation (2) above is multiplied by 20:

$$0.000001/\text{year} \times 20 \text{ years} = 0.00002 \text{ (or 2 in 100,000) over 20 years} \quad \textbf{(3)}$$

The risks for all of the contaminants in the installation'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 an installation can then be summed to give the installation'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, installation/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:

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

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*, non-cancer toxicity from exposure to mixtures of hazardous chemicals (EPA, 1991a). It is calculated for the offsite and noninvolved worker MEIs at each installation, 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 installation 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, 1995c).

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 most-exposed FTE ("worker equivalent") instead of the hazard index. Like the hazard index, the exposure index is an estimate of the worst-case, total non-cancer 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

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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 most-exposed FTE at any installation 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, 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 most-exposed FTE at any installation 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, worst-case accidents (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 non-worker 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 Installations 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)
- Unlikely (between 1 chance in 100 and 1 chance in 10,000)
- Very unlikely (between 1 chance in 10,000 and 1 chance in 1,000,000)
- Extremely unlikely (less than 1 in 1,000,000)

For example, incinerator ash explosions during the processing of LLW are considered to be anticipated, while a large aircraft impact with 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 installation.
- 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 installation (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 most-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 most-exposed generation of the hypothetical farm family, and all generations of the farm family from disposal of LLW and LLMW, by alternative and installation.
- 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-1 to represent the total estimated operations fatalities to waste management workers incinerating a particular waste under a regionalized alternative. The notation "E-1" 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-6 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-6 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.)

To place the risk estimates in this appendix in perspective, it may be useful to compare them to the exposure level guidelines in 40 CFR 300.430(e)(2) and (EPA, 1991b). According to those guidelines, the target exposure level (or risk goal) for an individual member of the public to known or suspected carcinogens is generally taken to be that concentration that poses an excess lifetime risk of cancer incidence between 1.0E-4 and 1.0E-6. It follows that individual risks of cancer incidence below 1.0E-6 are generally considered to meet this goal while risks above 1.0E-4 may indicate that action is necessary to reduce risks. Note that these guidelines should be considered as an attempt to define action levels and *not* to represent any value judgements about acceptable or unacceptable risks.

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).

Since the offsite and noninvolved worker MEIs at each installation receive the worst-case public exposures to contaminants (the per capita exposure to an entire population is always lower than the MEI's

exposure), readers might wish to compare the risks for these most-exposed receptors to the EPA guidelines above.

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 *installation level*. This is illustrated in the following example.

Consider a decentralized alternative (for example, Hypothetical Alternative 1) that affects the populations at 14 installations and a centralized alternative (Hypothetical Alternative 2) that affects the population at only 1 installation. If the total risks across all installations in Hypothetical Alternative 1 are *numerically* higher than the total risks for the one installation 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 *installation level* as well.

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

$$8.0E-1 \text{ (total risk for alternative)} \div 23{,}000{,}000 \text{ people affected overall} = 3.5E-8$$

This result, 3.5E-8, might be considered the "average" risk to an individual member of the program-wide 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 most-exposed member of the population.)

If this so-called "average" individual risk is compared to EPA risk assessment guidelines, it is found to be 1.5 orders of magnitude below 1.0E-6, or within what is considered to be the target risk range.

Although this "average" individual risk is *not* a formal construct in risk analysis, it may be useful in helping the reader compare the risks among alternatives or installations. "Average" risks will be brought to the reader's attention in the text and tables as needed to clarify the risks posed by particular alternatives or installations.

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 installation (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 (Section D.6).

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 installations 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.3.1.8. Transportation risks are presented in Appendix E.

Chapters 3 and 9 of the PEIS and the HLW technical report (ANL, 1995a) provide more detailed information on this waste including HLW inventories at DOE installations, 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 installation 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 and INEL until 2015; and in Storage Case 2 of the Centralized Alternative, Hanford stores all of the SRS and INEL 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 installations continues to store its own inventory of immobilized HLW awaiting ultimate disposal in a national geologic repository.
- In the Regionalized Alternative 1, 300 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, 300 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, 327 from INEL, and 300 from WVDP are transported to Hanford for interim storage until a geologic repository is available. The remaining canisters produced at SRS (2,199) and INEL (8,173) are stored onsite until the geologic repository is in operation. In Storage Case 2, Hanford stores all SRS and INEL canisters (a total of 28,372) and would require additional storage capacity.

Construction hazards were analyzed for the installations 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 installations ship their wastes to regional or central consolidation sites for interim storage. The numbers in parentheses are the numbers of canisters stored at the installation. 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 and INEL canisters (making a total of 28,372 HLW canisters at Hanford).

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 (300)
Decentralized (both storage cases)	Ship	—	—	—	—
	Store	Hanford[a] (15,000)	INEL[a] (8,500)	SRS[a] (4,572)	WVDP (300)
Regionalized 1 (both storage cases)	Ship	—	—	—	Store temporarily for 6 years then ship 300 to SRS
	Store	Hanford[a] (15,000)	INEL[a] (8,500)	SRS[a] (4,872)	
Regionalized 2 (both storage cases)	Ship	—	—	—	Store temporarily for 16 years then ship 300 to Hanford
	Store	Hanford[a] (15,300)	INEL[a] (8,500)	SRS[a] (4,572)	
Centralized—Storage Case 1	Ship	—	Ship 327 to Hanford	Ship 2,373 to Hanford	Ship 300 to Hanford
	Store	Hanford[a] (18,000)	INEL[a] (8,173)	SRS (2,199)	—
Centralized—Storage Case 2	Ship	—	Ship 8,500 to Hanford	Ship 4,572 to Hanford	Ship 300 to Hanford
	Store	Hanford[a] (28,372)	—	—	—

[a] Construction of a new storage facility is required.

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.

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 installation 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*, program-wide 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 program-wide 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 installation, 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 Program-Wide 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[b]	CI[c]	C&OF[d]
No Action	1.7	1.8	6.4	5.0E-1
Decentralized	3.7	2.7	9.8	9.8E-1
Regionalized 1	3.8	2.8	9.9	9.9E-1
Regionalized 2	3.7	2.8	9.9	9.2E-1
Centralized	4.0	3.0	1.0E1	9.9E-1

[a] Sum of fatalities from construction, operation, and cancer associated with exposure to radionuclides.
[b] CF—Cancer fatality associated with exposure to radionuclides.
[c] CI—Cancer incidence.
[d] C&OF—Construction and operational fatalities.

Table D.3.1-3. Program-Wide 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)	4.5E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.4	
	Genetic Effects	2.7E-1	
	Construction Fatalities		2.4E-2
	Construction Injuries		1.0E1
	Operation Fatalities		4.7E-1
	Operation Injuries		4.0E2

Table D.3.1–4. Program-Wide 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)	7.0E3	
	Cancer Fatalities	2.7	
	Cancer Incidence	9.8	
	Genetic Effects	4.2E-1	
	Construction Fatalities		2.0E-1
	Construction Injuries		8.8E1
	Operation Fatalities		7.7E-1
	Operation Injuries		6.5E2

Table D.3.1–5. Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM Workers	Dose (FTE-rem)	7.1E3	
	Cancer Fatalities	2.8	
	Cancer Incidence	9.9	
	Genetic Effects	4.2E-1	
	Construction Fatalities		2.0E-1
	Construction Injuries		8.9E1
	Operation Fatalities		7.8E-1
	Operation Injuries		6.6E2

Table D.3.1-6. Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM Workers	Dose (FTE-rem)	7.0E3	
	Cancer Fatalities	2.8	
	Cancer Incidence	9.9	
	Genetic Effects	4.2E-1	
	Construction Fatalities		2.0E-1
	Construction Injuries		8.8E1
	Operation Fatalities		7.1E-1
	Operation Injuries		6.0E2

Table D.3.1-7. Program-Wide 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)	7.5E3	
	Cancer Fatalities	3.0	
	Cancer Incidence	1.0E1	
	Genetic Effects	4.5E-1	
	Construction Fatalities		2.2E-1
	Construction Injuries		9.5E1
	Operation Fatalities		7.6E-1
	Operation Injuries		6.4E2

Table D.3.1-8. Risks Associated with Managing HLW Under Storage Case 1 of the No Action Alternative, by Installation

Installation	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	3.4E-1	2.8
INEL	0.0	0.0
SRS	1.3	3.4
WVDP	6.6E-2	1.7E-1
TOTAL	1.7	6.4

[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 Installation

Installation	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	1.8	4.7
INEL	5.7E-1	1.5
SRS	1.3	3.4
WVDP	6.6E-2	1.7E-1
TOTAL	3.7	9.8

[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 the Regionalized Alternative 1, by Installation

Installation	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	1.8	4.7
INEL	5.7E-1	1.5
SRS	1.4	3.6
WVDP	4.0E-2	1.1E-1
TOTAL	3.8	9.9

[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 the Regionalized Alternative 2, by Installation

Installation	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	1.9	4.8
INEL	5.7E-1	1.5
SRS	1.2	3.4
WVDP	5.8E-2	1.5E-1
TOTAL	3.7	9.9

[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 Installation

Installation	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	2.3	6.1
INEL	5.6E-1	1.5
SRS	1.0	2.7
WVDP	5.8E-2	1.5E-1
TOTAL	4.0	1.0E1

[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[a]	CI[b]	GE[c]	CF	CI	GE	CF	CI	GE	CF	CI	GE
No Action	7.2E-3	2.5E-2	1.1E-3	0.0	0.0	0.0	7.6E-3	2.7E-2	1.1E-3	1.2E-3	4.2E-3	1.8E-4
Decentralized	7.2E-3	2.5E-2	1.1E-3	8.0E-4	2.8E-3	1.2E-4	7.6E-3	2.7E-2	1.1E-3	1.2E-3	4.2E-3	1.8E-4
Regionalized 1	7.2E-3	2.5E-2	1.1E-3	8.0E-4	2.8E-3	1.2E-4	7.6E-3	2.7E-2	1.1E-3	0.0	0.0	0.0
Regionalized 2	7.2E-3	2.5E-2	1.1E-3	8.0E-4	2.8E-3	1.2E-4	7.6E-3	2.7E-2	1.1E-3	0.0	0.0	0.0
Centralized	7.6E-3	2.7E-2	1.1E-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]CF—Cancer fatalities.
[b]CI—Cancer incidence.
[c]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[a]	OI[b]	OF	OI	OF	OI	OF	OI
No Action	3.2E-3	2.8	0.0	0.0	3.4E-3	2.9	5.4E-4	4.6E-1
Decentralized	3.2E-3	2.8	3.6E-4	3.1E-1	3.4E-3	2.9	5.4E-4	4.6E-1
Regionalized 1	3.2E-3	2.8	3.6E-4	3.1E-1	3.4E-3	2.9	0.0	0.0
Regionalized 2	3.2E-3	2.8	3.6E-4	3.1E-1	3.4E-3	2.9	0.0	0.0
Centralized	3.4E-3	2.9	0.0	0.0	0.0	0.0	0.0	0.0

[a]OF—Operational fatalities.
[b]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[a]	CI[b]	GE[c]	OF[d]	OI[e]	CnF[f]	CnI[g]
Centralized	1.1	3.9	1.7E-1	3.9E-2	3.3E1	6.7E-2	2.9E1

[a]CF—Cancer fatalities.
[b]CI—Cancer incidence.
[c]GE—Genetic effects.
[d]OF—Operational fatalities.
[e]OI—Operational injuries and illnesses.
[f]CnF—Construction fatalities.
[g]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). Program-wide fatalities from cancer and physical hazards range from 1.7 to 4.0. 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 installations 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 slightly more than a factor of two. This increased risk is due to the relatively long time that SRS, Hanford, and INEL store their canisters—42 to 45 years at all three installations. These long storage periods are based on the assumption that the national geologic repository accepts 800 canisters/year; therefore, 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 installation

to another but the total number of canisters at all installations, 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 (9.2E-1 to 9.9E-1) are about two times higher than the risks for Storage Case 1 of the No Action Alternative (5.0E-1). 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 installations (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, SRS, and WVDP 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 installation 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 installation. 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 program-wide summary of the risks of cancer incidence and cancer fatality to all receptors, by accident type and installation. Table D.3.1-17 provides the sizes of the offsite, noninvolved worker, and worker populations for each installation. 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 Installation

Accident	Installation	Offsite Population		Offsite MEI[a]		Noninvolved Worker Population		Noninvolved Worker MEI		Workers[b]	
		CF[c]	CI[d]	CF	CI	CF	CI	CF	CI	CF	CI
Filtered Canister Breach	Hanford	1.4E-3	4.7E-3	3.3E-8	1.1E-7	1.2E-7	4.1E-7	1.2E-9	4.0E-9	3.7E-4	1.3E-3
	SRS	1.2E-7	4.0E-7	3.6E-12	1.2E-11	9.4E-9	3.2E-8	4.0E-11	1.4E-10	1.3E-3	4.6E-3
	WVDP	4.9E-7	1.7E-6	1.8E-10	6.2E-10	4.2E-9	1.4E-8	2.4E-11	8.1E-11	3.3E-4	1.2E-3
Unfiltered Canister Breach	Hanford	1.3E-1	4.3E-1	3.0E-6	1.0E-5	4.0E-3	1.3E-2	3.9E-5	1.3E-4	3.7E-4	1.3E-3
	SRS	5.8E-2	2.0E-1	1.8E-6	6.1E-6	4.7E-3	1.6E-2	2.0E-5	6.9E-5	1.3E-3	4.6E-3
	WVDP	2.4E-1	8.3E-1	9.1E-5	3.1E-4	2.1E-3	7.1E-3	1.2E-5	4.0E-5	3.3E-4	1.2E-3

[a] MEI—Most-exposed individual.
[b] Worker exposures for a particular installation are the same in both accidents.
[c] CF—Risk of cancer fatality associated with radiological exposure.
[d] CI—Risk of cancer incidence associated with radiological exposure.

Table D.3.1-17. Size of Offsite, Noninvolved Worker, and Worker Populations Affected by the Risks from Potential HLW Storage Accidents, by Installation

Installation	Offsite Population	Noninvolved Worker Population	Worker Population
Hanford	377,645	8,674	4
SRS	620,618	15,996	4
WVDP	1,698,391	960	4

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

Accident Type	Radionuclide and Dose, by Installation		
	Hanford	SRS	WVDP
Filtered Canister Breach	Iodine-129 2.8 person-rem	Strontium-90 7.8E-5 person-rem	Cesium-137 3.9E-4 person-rem
Unfiltered Canister Breach	Cesium-137 108 person-rem	Strontium-90 39.2 person-rem	Cesium-137 197 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 2 to 6 orders of magnitude greater for the unfiltered canister breach than for the filtered accident.

Recall that cancer incidence risks to the MEI between 1.0E-4 and 1.0E-6 are generally regarded as within the target risk range according to EPA risk assessment guidelines (see Section D.2.14). In the filtered canister breach, cancer incidence and fatality risks to all offsite and noninvolved worker receptors are 1 to 5 orders of magnitude below 1.0E-6. In the unfiltered canister breach, cancer incidence and fatality risks exceed 1.0E-4 for the offsite MEI at WVDP and the noninvolved worker MEI at Hanford, and are in the E-6 to E-5 range for all remaining offsite and noninvolved worker MEIs.

At Hanford, the filtered canister breach accident risks for both the offsite population and MEI are 2 to 4 orders of magnitude greater than the analogous risks at SRS and WVDP (see Table D.3.1-16). This is because Hanford has iodine-129 in its inventory. Iodine-129 is a volatile gas, not a particulate, so HEPA filtration is not highly effective in removing it. In addition, iodine-129 is very biologically dangerous when taken into the body because it bioaccumulates in the thyroid and can severely damage thyroid tissue. However, while iodine-129 contributes equally to the risks in both the filtered and unfiltered accident scenarios at Hanford, its contribution to the unfiltered canister breach accident risks are outweighed by the risks from cesium-137.

In both accident scenarios, strontium-90 contributes most of the offsite population risk at SRS and cesium-137 is the major contributor at WVDP (see Table D.3.1-18). At Hanford, the controlling radionuclides are iodine-129 in the filtered canister breach scenario and cesium-137 in the unfiltered breach scenario. In all circumstances, the predominant exposure routes are inhalation and, to a lesser extent, ingestion.

Worker exposure is the same in both accident scenarios (see Table D.3.1-16). Worker risks do not differ appreciably among installations, and are highest at SRS by less than 0.5 orders of magnitude. The controlling radionuclides for worker exposure are plutonium-238 at SRS and americium-241 at Hanford and WVDP; 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. More than 30 installations within the DOE complex generate LLW; following are the installations considered in the PEIS (note the abbreviations used in this section):

- 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
- 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

Note that treatment risks were estimated separately for the three sites comprising ORR (e.g., ORNL, Y-12, and K-25), whereas disposal risks were calculated for the combined three sites (i.e., for the ORR as a single, overall installation). Treatment risks were calculated separately 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 combined based on the assumption that disposal of LLW from all three sites takes place at one central ORR facility.

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, 1995c) provide more detailed information on this waste, including LLW inventories at DOE installations, 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 installations transport LLW to six installations (Hanford, INEL, LANL, NTS, ORR, and SRS) for disposal under current arrangements. All installations use existing treatment facilities.
- The Decentralized Alternative: Twelve installations dispose of all LLW projected to be generated over the next 20 years. Minimum treatment at each installation is assumed.
- The Regionalized Alternatives (seven alternatives): 2, 6, or 10 installations 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 installation (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 installations, and the risks associated with various disposal configurations.

Table D.3.2-1 depicts the overall treatment and storage schemes for the LLW alternatives.

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
No Action	10[b]	6				T[c]D[d]	TD	D	T	D	TD	T			T		TD
Dec.[a]		16	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Reg. 1		12			D	D	D	D	D	D	D	D	D	D	D		D
Reg. 2	11	12			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											

[a] Alternative abbreviations are: Dec. = Decentralized; Reg. = Regionalized; and Cen. = Centralized.
[b] Ten installations use existing facilities for volume reduction. Three sites not listed as major installations above (LBL, RMI, and Mound) include volume reduction facilities.
[c] T—Treatment installation. In this context, treatment entails volume reduction using thermal organic destruction, size reduction (shredding, etc.), and compaction followed by solidification. All installations perform minimum treatment in all alternatives; this consists of solidifying liquids and powdered material, packaging, and shipment.
[d] D—Disposal installation. Each of the 6-installation disposal alternatives uses the same installations, and each of the 12-installation disposal alternatives uses the same 12 installations.

Note that for the purposes of this risk analysis, the waste loads from four smaller generators have been added to the inventories of larger generators. Specifically, the ORISE waste load is combined with the ORNL inventory; the ANL-W and NRF waste loads are added to the INEL inventory; and the SNL-CA waste load is combined with the LLNL inventory.

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 installations west of the Mississippi River and tumulus (above-ground vault) disposal will be used at eastern installations. 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 installations. 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 installation 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*, program-wide 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, which can be found at the end of Section D.3.2.4.
- Table D.3.2–3 presents an overview, by alternative, of the program-wide risks associated with disposal of LLW. This table summarizes the risks of cancer fatalities and cancer incidence for the most-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, located at the end of Section D.3.2.4.
- 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 installation and alternative.

Table D.3.2–2. Summary of Program-Wide Risks Associated with Treatment of LLW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF[a]	CI[b]	CF	CI	CF	CI	C&OF[c]
No Action	1.3E-2	4.5E-2	4.3E-4	1.5E-3	1.1	3.7	2.9
Minimum Treatment Alternatives							
Decentralized	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.5E-1	2.6	2.1
Regionalized 1	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.5E-1	2.5	2.1
Regionalized 3	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.5E-1	2.5	2.3
Regionalized 6	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.7E-1	2.7	2.6
Regionalized 7	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.7E-1	2.7	2.6
Centralized 1	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.7E-1	2.7	2.6
Centralized 2	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.7E-1	2.7	2.6
Volume Reduction Alternatives							
Regionalized 2	6.4E-1	2.2	6.6E-3	2.2E-2	1.1	3.8	4.8
Regionalized 4	9.7E-2	3.3E-1	1.9E-3	6.5E-3	1.2	4.3	4.8
Centralized 3	1.0E-1	3.4E-1	2.1E-3	7.3E-3	1.2	4.3	4.8
Centralized 4	1.0E-1	3.4E-1	2.1E-3	7.3E-3	1.2	4.3	4.8
Regionalized 5	1.2E-1	4.0E-1	1.4E-3	4.8E-3	1.4	4.8	4.8
Centralized 5	9.8E-2	3.33E-1	1.1E-3	3.7E-3	2.2	7.5	4.3

[a] CF—cancer fatality associated with radionuclide exposure.
[b] CI—cancer incidence associated with exposure to radionuclides.
[c] C&OF—fatalities due to the physical hazards of constructing and operating waste management facilities.

Table D.3.2-3. Summary of Program-Wide 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[a]	CI[b]	CF	CI	CF	CI	C&OF[c]
No Action	5.7E-3	2.0E-2	7.6E-2	2.6E-1	3.0	10	3.8
Decentralized Disposal							
Decentralized	6.4E-2	2.2E-1	1.2	3.9	2.3	7.9	5.9
Regionalized Disposal							
Regionalized 1	1.5E-3	5.1E-3	2.2E-2	7.4E-2	2.2	7.6	5.7
Regionalized 2	5.2E-3	1.8E-2	7.2E-2	2.5E-1	1.8	6.3	4.2
Regionalized 3	1.3E-3	4.3E-3	1.7E-2	5.8E-2	2.4	8.3	5.3
Regionalized 4	1.4E-2	4.8E-2	1.9E-1	6.3E-1	1.8	6.3	3.9
Regionalized 5	1.4E-2	4.8E-2	1.9E-1	6.3E-1	1.8	6.3	3.9
Regionalized 6	1.6E-2	5.6E-2	2.2E-1	7.3E-1	1.8	6.2	6.4
Regionalized 7	1.7E-4	5.9E-4	1.8E-4	6.3E-3	1.8	6.2	6.3
Centralized Disposal							
Centralized 1	4.8E-3	1.6E-2	6.4E-2	2.2E-1	2.8	9.7	1.4
Centralized 2	0.00	0.00	0.00	0.00	2.8	9.7	1.3
Centralized 3	9.2E-3	3.1E-2	1.2E-1	4.2E-1	1.8	6.1	7.5E-1
Centralized 4	0.00	0.00	0.00	0.00	1.8	6.2	8.5E-1
Centralized 5	9.2E-3	3.1E-2	1.2E-1	4.2E-1	1.8	6.2	8.8E-1

[a] CF—Risk of cancer fatality associated with exposure to radionuclides.
[b] CI—Risk of cancer incidence associated with exposure to radionuclides.
[c] 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	32,597,069	115,729	16,656
Decentralized	38,321,357	115,729	9,640
Regionalized 1	32,582,803	115,729	9,663
Regionalized 3	32,582,803	115,729	10,321
Regionalized 6	32,582,803	115,729	11,579
Regionalized 7	32,582,803	115,729	11,845
Centralized 1	32,582,803	115,729	11,601
Centralized 2	32,582,803	115,729	11,867
Regionalized 2	35,347,392	118,185	22,483
Regionalized 4	32,582,803	115,729	22,469
Centralized 3	32,597,069	119,485	22,489
Centralized 4	32,597,069	119,485	22,489
Regionalized 5	32,582,803	115,729	22,602
Centralized 5	32,582,803	115,729	19,855

Table D.3.2–5. Summary of Program-Wide Risks Associated with Treatment of LLW: Risks To the Offsite and Noninvolved Worker Most-Exposed Individuals, by Alternative

Alternative	Offsite MEI[a]		Noninvolved Worker MEI	
	CF[b]	CI[c]	CF	CI
No Action	3.5E-7	1.2E-6	3.4E-7	1.2E-6
Decentralized	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Regionalized 1	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Regionalized 3	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Regionalized 6	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Regionalized 7	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Centralized 1	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Centralized 2	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Regionalized 2	6.3E-6	2.1E-5	1.8E-6	6.2E-6
Regionalized 4	2.3E-6	7.9E-6	8.5E-7	2.9E-6
Centralized 3	2.3E-6	7.9E-6	1.1E-6	3.6E-6
Centralized 4	2.3E-6	7.9E-6	1.1E-6	3.6E-6
Regionalized 5	1.4E-6	4.9E-6	8.5E-7	2.9E-6
Centralized 5	1.5E-6	5.2E-6	1.7E-6	5.8E-6

[a] MEI—Most-exposed individual.
[b] CF—Risk of cancer fatality associated with exposure to radionuclides.
[c] CI—Risk of cancer incidence associated with exposure to radionuclides.

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

Alt.[a]	Installation																					
	ANL-E	BNL	FEMP	Hanford	INEL	KCP	KAPL-K	LBL	LLNL	LANL	Mound	NTS	K-25	ORNL	Y-12	PGDP	Pantex	Pinellas	Ports	RFETS	SNL/NM	SRS
No Action	Pu-238[b] 7.0E-7[c]			Pu-238 2.3E-7	Co-60 1.3E-6	U-238 5.5E-10	Co-60 5.3E-4	H-3 7.6E-4	U-238 2.4E-7	Pu-238 1.1E-4	Pu-238 4.3E-8		U-238 1.2E-9	Pu-238 1.0E-1	U-238 1.8E-8	U-238 1.8E-8	H-3 1.6E-7	H-3 1.8E-8	U-238 1.6E-9	Pu-238 4.9E-8	U-238 8.8E-7	H-3 4.1E-4
Dec.	Pu-238 7.6E-7			Pu-238 1.5E-6	Co-60 7.6E-7	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 8.0E-9	Pu-238 3.3E-6	U-238 1.9E-8	U-238 2.8E-7	H-3 8.0E-8	H-3 1.8E-8	U-238 2.8E-10	Pu-238 1.4E-7	U-238 8.9E-7	H-3 6.2E-6
Reg. 1	Pu-238 7.6E-7			Pu-238 1.5E-6	Co-60 7.6E-7	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 8.0E-9	Pu-238 3.3E-6	U-238 1.9E-8	U-238 2.8E-7	H-3 8.0E-8	H-3 1.8E-8	U-238 2.8E-10	Pu-238 1.4E-7	U-238 9.1E-7	H-3 6.2E-6
Reg. 3	Pu-238 7.6E-7			Pu-238 1.5E-6	Co-60 7.6E-7	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 8.0E-9	Pu-238 3.3E-6	U-238 1.9E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 6.2E-6
Reg. 6	Pu-238 7.6E-7			Pu-238 1.5E-6	Co-60 1.2E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 1.1E-7	Pu-238 3.3E-6	U-238 7.8E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 6.2E-6
Reg. 7	Pu-238 7.6E-7			Pu-238 2.2E-6	Co-60 1.2E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 1.1E-7	Pu-238 3.3E-6	U-238 7.8E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 6.2E-6
Cen. 1	Pu-238 7.6E-7			Pu-238 1.5E-6	Co-60 1.2E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 1.1E-7	Pu-238 3.3E-6	U-238 7.8E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 6.2E-6
Cen. 2	Pu-238 7.6E-7			Pu-238 2.2E-6	Co-60 1.2E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 1.1E-7	Pu-238 3.3E-6	U-238 7.8E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 6.2E-6
Reg. 2	Pu-238 7.6E-7		H-3 2.0E-1	Pu-238 1.9E-6	Co-60 1.3E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 3.8E-1	U-238 1.0E-1	Pu-238 4.7E-8		U-238 8.0E-9	C-14 4.9E-6	U-238 1.9E-8	U-238 1.6E-6	H-3 8.1E-8	H-3 1.8E-8	Co-60 5.8E-5	Pu-238 7.4E-5	U-238 9.1E-7	H-3 4.1E-4
Reg. 4	Pu-238 7.6E-7			H-3 5.0E-1	Co-60 1.3E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1		U-238 1.0E-1	Pu-238 4.7E-8		U-238 8.0E-9	U-238 5.6E-6	U-238 1.9E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	H-3 2.0E-1	Pu-238 7.4E-5	U-238 9.1E-7	H-3 4.1E-4
Cen. 3 Cen. 4	Pu-238 7.6E-7			H-3 5.0E-1	Co-60 1.3E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1		U-238 1.0E-1	Pu-238 4.7E-8	Pu-238 4.8E-5	U-238 8.0E-9	U-238 5.6E-6	U-238 1.9E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	H-3 2.0E-1	Pu-238 7.4E-5	U-238 9.1E-7	H-3 4.1E-4
Reg. 5	Pu-238 7.6E-7			H-3 5.0E-1	U-238 3.4E-4	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1		Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 8.0E-9	H-3 5.0E-1	U-238 1.9E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 4.1E-4
Cen. 5	Pu-238 7.6E-7			H-3 7.0E-1	Co-60 7.6E-7	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1		Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 8.0E-9	Pu-238 3.3E-6	U-238 1.9E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	Co-60 5.0E-6

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

D.3.2.4 Results of the LLW Human Health Risk Analysis for Routine Operations

D.3.2.4.1 *Program-Wide 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 1.5 orders of magnitude for all alternatives (1.3E-2 to 6.4E-1). 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 (1.3E-2), the Decentralized Alternative, Regionalized Alternatives 1, 3, 6, 7, and Centralized Alternatives 1 and 2. All are in the E-2 order of magnitude and affect a total population of 32 million to 38 million people. 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-2 to 1.2E-1 over a total affected population of approximately 32.5 million) and are about 0.5 to 1 order 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-1 cancer fatalities over 32.5 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-1 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 Ports in both the Decentralized and Regionalized 1 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-1 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-1.

Noninvolved Worker Population. The trends in program-wide health risks to the noninvolved worker population are similar to those observed for the offsite population; both the program-wide 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-3 cancer fatalities in a population of 118,185) are about three to six times higher than in the other volume reduction alternatives.

The risks in the No Action, Decentralized, Regionalized 1, 3, 6, 7, and Centralized 1 and 2 Alternatives are nearly identical to one another (ranging from approximately 2E-4 to 4E-4) 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.

Most-Exposed Noninvolved Workers and Most-Exposed Offsite Individuals. Radiological exposure risks to the noninvolved worker and offsite MEIs are lowest in the No Action, Decentralized, Regionalized 1, 3, 6, 7, and Centralized 1 and 2 Alternatives; slightly higher in Regionalized 4 and 5 and Centralized 3, 4, and 5; and highest in Regionalized 2. This trend generally parallels that seen for the overall noninvolved worker and offsite populations.

The program-wide risk of cancer incidence for both MEIs is in the E-5 to E-6 range in Regionalized 2, 4, and 5 and Centralized 3, 4, and 5 (see Table D.3.2–5), and are considered to meet target exposure levels according to EPA guidelines. Across the program, the highest risk of cancer fatality for both MEIs is in Regionalized 2 (an estimated risk of 6.3E-6 for the offsite MEI and 1.8E-6 for the noninvolved

worker MEI). At the installation level, the highest risks of cancer fatality to the offsite MEI are at FEMP (4.4E-6) and LLNL (6.3E-6) in Regionalized 2; Ports (2.3E-6) in Regionalized 4; Hanford (1.0E-6) and Ports (2.3E-6) in Centralized 3 and 4; ORNL (1.4E-6) in Regionalized 5; and Hanford (1.5E-6) in Regionalized 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-6.

Workers. The program-wide 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 7.5E-1 cancer fatalities across 9,640 to 11,867 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 program-wide cancer fatality risk is incurred in Centralized Alternative 5 (2.2 over a total population of 19,855 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 (8.5E-1), 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 (2.01) and the volume reduction alternatives (2.4 to 2.73) than for the minimum treatment alternatives (1.17 to 1.44). 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-2 to E-1 range) except at KCP and Pinellas (E-3 order of magnitude), which have much smaller waste loads to treat and employ fewer workers (21 to 26 and 11 to 13 FTEs, respectively) than are needed at other installations.

By a slight margin, ORNL poses 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 1.15 to 1.77) 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 ORNL in the volume-reduction alternatives reflects consolidation of waste loads at ORNL for treatment, additional construction of treatment facilities, and the presence of 10 times more 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 *Program-Wide 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 1.2 cancer fatalities over 10,000 years. Estimated cancer fatalities for workers during disposal are very similar across alternatives, ranging from 1.8 to 3.0; worker risks tend to increase as the waste load to be disposed of becomes larger and as more disposal facility construction is required.

Most-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-4, indicating exposure levels that might be considered above the target exposure level if compared with the EPA guidelines discussed in Section D.2.14. 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 program-wide cancer fatality risks are 6.4E-2 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 program-wide 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 3, 4, and 7, and Centralized 2 and 4 Alternatives; at Pantex in the Decentralized and Regionalized 1 and 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 1.6E-2). 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 1.8 to 3.0 for cancer fatality and 6.1 to 10 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. 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 5.3E-1 to 2.1). 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 7.5E-1 and 2.2. Overall, worker risks at particular installations seem to be driven primarily by waste consolidation and facility construction.

The program-wide 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-7 in Regionalized Alternative 5 (which involves minimum treatment) to 1.9E-4 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 1.6E-3 to 8.2E-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 within 0.5 orders of magnitude (1.6E-3 at NTS and 4.8E-3 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 three. 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 program-wide risks of cancer incidence to the MEL of the hypothetical farm family exceed the target exposure levels if comparison is made to EPA risk assessment guidelines (Section D.2.14). Recall that this is a worst-case 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; program-wide 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.

Table D.3.2–7. Program-Wide 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)	8.5E-1	
	Cancer Fatalities	4.3E-4	
	Cancer Incidence	1.5E-3	
	Genetic Effects	8.5E-5	
Noninvolved Worker MEI	Dose (rem)	6.8E-4	
	Cancer Fatalities	3.4E-7	
	Cancer Incidence	1.2E-6	
	Genetic Effects	6.8E-8	
	Hazard Index		
Offsite Population	Dose (person-rem)	2.7E1	
	Cancer Fatalities	1.3E-2	
	Cancer Incidence	4.5E-2	
	Genetic Effects	2.7E-3	
Offsite MEI	Dose (rem)	7.0E-4	
	Cancer Fatalities	3.5E-7	
	Cancer Incidence	1.2E-6	
	Genetic Effects	7.0E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	2.6E3	
	Cancer Fatalities	1.1	
	Cancer Incidence	3.7	
	Genetic Effects	1.6E-1	
	Exposure Index		
	Construction Fatalities		8.5E-1
	Construction Injuries		3.7E2
	Operation Fatalities		2.0
	Operation Injuries		1.7E3

Table D.3.2–8. Program-Wide 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-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.9E3	
	Cancer Fatalities	7.5E-1	
	Cancer Incidence	2.6	
	Genetic Effects	1.1E-1	
	Exposure Index		
	Construction Fatalities		9.6E-1
	Construction Injuries		4.2E2
	Operation Fatalities		1.2
	Operation Injuries		9.9E2

Table D.3.2-9. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.8E3	
	Cancer Fatalities	7.3E-1	
	Cancer Incidence	2.5	
	Genetic Effects	1.1E-1	
	Exposure Index		
	Construction Fatalities		9.6E-1
	Construction Injuries		4.2E2
	Operation Fatalities		1.2
	Operation Injuries		9.9E2

Table D.3.2-10. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.8E3	
	Cancer Fatalities	7.3E-1	
	Cancer Incidence	2.5	
	Genetic Effects	1.1E-1	
	Exposure Index		
	Construction Fatalities		1.0
	Construction Injuries		4.5E2
	Operation Fatalities		1.3
	Operation Injuries		1.1E3

Table D.3.2-11. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 6, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.9E3	
	Cancer Fatalities	7.7E-1	
	Cancer Incidence	2.7	
	Genetic Effects	1.2E-1	
	Exposure Index		
	Construction Fatalities		1.2
	Construction Injuries		5.0E2
	Operation Fatalities		1.4
	Operation Injuries		1.2E3

Table D.3.2–12. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 7, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.9E3	
	Cancer Fatalities	7.7E-1	
	Cancer Incidence	2.7	
	Genetic Effects	1.2E-1	
	Exposure Index		
	Construction Fatalities		1.2
	Construction Injuries		5.2E2
	Operation Fatalities		1.4
	Operation Injuries		1.2E3

Table D.3.2-13. Program-Wide 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-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.9E3	
	Cancer Fatalities	7.7E-1	
	Cancer Incidence	2.7	
	Genetic Effects	1.2E-1	
	Exposure Index		
	Construction Fatalities		1.2
	Construction Injuries		5.0E2
	Operation Fatalities		1.4
	Operation Injuries		1.2E3

Table D.3.2–14. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.9E3	
	Cancer Fatalities	7.7E-1	
	Cancer Incidence	2.7	
	Genetic Effects	1.2E-1	
	Exposure Index		
	Construction Fatalities		1.2
	Construction Injuries		5.2E2
	Operation Fatalities		1.4
	Operation Injuries		1.2E3

Table D.3.2-15. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	1.3E1	
	Cancer Fatalities	6.6E-3	
	Cancer Incidence	2.2E-2	
	Genetic Effects	1.3E-3	
Noninvolved Worker MEI	Dose (rem)	3.6E-3	
	Cancer Fatalities	1.8E-6	
	Cancer Incidence	6.2E-6	
	Genetic Effects	3.6E-7	
	Hazard Index		
Offsite Population	Dose (person-rem)	1.3E3	
	Cancer Fatalities	6.4E-1	
	Cancer Incidence	2.2	
	Genetic Effects	1.3E-1	
Offsite MEI	Dose (rem)	1.3E-2	
	Cancer Fatalities	6.3E-6	
	Cancer Incidence	2.1E-5	
	Genetic Effects	1.3E-6	
	Hazard Index		
WM Workers	Dose (FTE-rem)	2.7E3	
	Cancer Fatalities	1.1	
	Cancer Incidence	3.8	
	Genetic Effects	1.7E-1	
	Exposure Index		
	Construction Fatalities		2.1
	Construction Injuries		9.2E2
	Operation Fatalities		2.7
	Operation Injuries		2.3E3

Table D.3.2-16. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.8	
	Cancer Fatalities	1.9E-3	
	Cancer Incidence	6.5E-3	
	Genetic Effects	3.8E-4	
Noninvolved Worker MEI	Dose (rem)	1.7E-3	
	Cancer Fatalities	8.5E-7	
	Cancer Incidence	2.9E-6	
	Genetic Effects	1.7E-7	
	Hazard Index		
Offsite Population	Dose (person-rem)	2.0E2	
	Cancer Fatalities	9.7E-2	
	Cancer Incidence	3.3E-1	
	Genetic Effects	2.0E-2	
Offsite MEI	Dose (rem)	4.6E-3	
	Cancer Fatalities	2.3E-6	
	Cancer Incidence	7.9E-6	
	Genetic Effects	4.6E-7	
	Hazard Index		
WM Workers	Dose (FTE-rem)	3.1E3	
	Cancer Fatalities	1.2	
	Cancer Incidence	4.3	
	Genetic Effects	1.8E-1	
	Exposure Index		
	Construction Fatalities		2.1
	Construction Injuries		9.3E2
	Operation Fatalities		2.7
	Operation Injuries		2.3E3

Table D.3.2–17. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternatives 3 and 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	4.3	
	Cancer Fatalities	2.1E-3	
	Cancer Incidence	7.3E-3	
	Genetic Effects	4.3E-4	
Noninvolved Worker MEI	Dose (rem)	2.1E-3	
	Cancer Fatalities	1.1E-6	
	Cancer Incidence	3.6E-6	
	Genetic Effects	2.1E-7	
	Hazard Index		
Offsite Population	Dose (person-rem)	2.0E2	
	Cancer Fatalities	1.0E-1	
	Cancer Incidence	3.4E-1	
	Genetic Effects	2.0E-2	
Offsite MEI	Dose (rem)	4.6E-3	
	Cancer Fatalities	2.3E-6	
	Cancer Incidence	7.9E-6	
	Genetic Effects	4.6E-7	
	Hazard Index		
WM Workers	Dose (FTE-rem)	3.1E3	
	Cancer Fatalities	1.2	
	Cancer Incidence	4.3	
	Genetic Effects	1.9E-1	
	Exposure Index		
	Construction Fatalities		2.1
	Construction Injuries		9.3E2
	Operation Fatalities		2.7
	Operation Injuries		2.3E3

Table D.3.2–18. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	2.8	
	Cancer Fatalities	1.4E-3	
	Cancer Incidence	4.8E-3	
	Genetic Effects	2.8E-4	
Noninvolved Worker MEI	Dose (rem)	1.7E-3	
	Cancer Fatalities	8.5E-7	
	Cancer Incidence	2.9E-6	
	Genetic Effects	1.7E-7	
	Hazard Index		
Offsite Population	Dose (person-rem)	2.4E2	
	Cancer Fatalities	1.2E-1	
	Cancer Incidence	4.0E-1	
	Genetic Effects	2.4E-2	
Offsite MEI	Dose (rem)	2.9E-3	
	Cancer Fatalities	1.4E-6	
	Cancer Incidence	4.9E-6	
	Genetic Effects	2.9E-7	
	Hazard Index		
WM Workers	Dose (FTE-rem)	3.5E3	
	Cancer Fatalities	1.4	
	Cancer Incidence	4.8	
	Genetic Effects	2.1E-1	
	Exposure Index		
	Construction Fatalities		2.1
	Construction Injuries		9.1E2
	Operation Fatalities		2.7
	Operation Injuries		2.3E3

Table D.3.2–19. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	2.2	
	Cancer Fatalities	1.1E-3	
	Cancer Incidence	3.7E-3	
	Genetic Effects	2.2E-4	
Noninvolved Worker MEI	Dose (rem)	3.4E-3	
	Cancer Fatalities	1.7E-6	
	Cancer Incidence	5.8E-6	
	Genetic Effects	3.4E-7	
	Hazard Index		
Offsite Population	Dose (person-rem)	2.0E2	
	Cancer Fatalities	9.8E-2	
	Cancer Incidence	3.3E-1	
	Genetic Effects	2.0E-2	
Offsite MEI	Dose (rem)	3.1E-3	
	Cancer Fatalities	1.5E-6	
	Cancer Incidence	5.2E-6	
	Genetic Effects	3.1E-7	
	Hazard Index		
WM Workers	Dose (FTE-rem)	5.4E3	
	Cancer Fatalities	2.2	
	Cancer Incidence	7.5	
	Genetic Effects	3.2E-1	
	Exposure Index		
	Construction Fatalities		1.9
	Construction Injuries		8.5E2
	Operation Fatalities		2.4
	Operation Injuries		2.0E3

Table D.3.2–20. Program-Wide Risks Associated with Treatment of LLW Under the No Action Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
INEL	153061 / 2169	1.4E-6	1.7E-10	6.1E-1	4.7E-6	5.8E-10	8.7E-1
Hanford	377645 / 997	4.2E-7	8.6E-12	3.2E-1	1.4E-6	2.9E-11	5.4E-1
KAPL-K	1290172 / 925	5.3E-4	1.2E-8	1.7E-1	1.8E-3	4.0E-8	1.8E-2
LBL	5856829 / 236	7.6E-4	1.2E-8	5.1E-2	2.6E-3	4.1E-8	2.9E-2
LANL	159152 / 920	1.9E-4	2.0E-8	3.3E-1	6.6E-4	6.9E-8	6.2E-1
NTS	14266 / 0	0.00	0.00	0.00	0.00	0.00	0.00
ORNL	881652 / 914	1.1E-2	3.5E-7	2.3E-1	3.8E-2	1.2E-6	2.0E-1
SNL-NM	610714 / 277	1.7E-6	6.8E-11	5.1E-2	5.8E-6	2.3E-10	1.8E-3
SRS	620618 / 3032	5.9E-4	5.6E-9	8.5E-1	2.0E-3	1.9E-8	1.2
KCP	1729833 / 13	1.0E-9	4.6E-14	2.4E-3	3.4E-9	1.6E-13	1.3E-4
LLNL	6324234 / 426	3.5E-7	5.8E-12	7.0E-2	1.2E-6	2.0E-11	4.1E-3
Mound	3032983 / 710	9.4E-8	5.5E-12	1.4E-1	3.2E-7	1.9E-11	7.2E-3
K-25	871406 / 708	1.3E-9	2.8E-14	1.2E-1	4.4E-9	9.6E-14	1.5E-2
Y-12	895379 / 1101	1.9E-8	7.2E-13	1.9E-1	6.6E-8	2.4E-12	2.3E-2
PGDP	500502 / 654	2.0E-8	2.3E-12	1.2E-1	6.9E-8	7.6E-12	7.8E-3
Pantex	265185 / 1040	1.8E-7	1.6E-11	1.8E-1	6.3E-7	5.3E-11	1.2E-2
Pinellas	2532174 / 26	1.8E-8	3.8E-13	4.7E-3	6.0E-8	1.3E-12	2.4E-4
Ports	639602 / 1450	1.7E-9	2.1E-13	2.5E-1	5.7E-9	7.2E-13	2.0E-2
RFETS	2171877 / 656	1.2E-7	1.7E-12	1.2E-1	4.1E-7	5.6E-12	6.5E-3
ANL-E	7939785 / 402	2.3E-6	1.3E-11	1.1E-1	8.0E-6	4.4E-11	1.5E-1
TOTAL		1.3E-2	3.5E-7	3.9	4.5E-2	1.2E-6	3.7

[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 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.
[d] Offsite.

Table D.3.2–21. Program-Wide Risks Associated with Treatment of LLW Under the Decentralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
Hanford	377645 / 577	2.7E-6	5.5E-11	2.2E-1	9.1E-6	1.9E-10	3.5E-1
INEL	153061 / 677	8.0E-7	9.9E-11	3.2E-1	2.7E-6	3.4E-10	5.8E-1
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LLNL	6324234 / 191	1.0E-2	1.6E-7	5.0E-2	3.4E-2	5.5E-7	8.9E-3
LANL	159152 / 653	2.1E-4	2.2E-8	2.8E-1	7.1E-4	7.5E-8	4.9E-1
ORNL	881652 / 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL-NM	610714 / 187	1.8E-6	7.1E-11	6.5E-2	6.1E-6	2.4E-10	7.6E-2
SRS	620618 / 1986	1.9E-5	1.7E-10	6.6E-1	6.3E-5	5.9E-10	7.9E-1
BNL	5738554 / 0	0.00	0.00	0.00	0.00	0.00	0.00
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 / 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 / 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 / 501	3.2E-7	3.6E-11	1.1E-1	1.1E-6	1.2E-10	5.2E-3
Pantex	265185 / 446	8.3E-8	7.1E-12	9.8E-2	2.8E-7	2.4E-11	8.9E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 / 730	2.4E-10	3.1E-14	1.5E-1	8.3E-10	1.1E-13	1.6E-2
RFETS	2171877 / 298	3.6E-7	4.9E-12	7.1E-2	1.2E-6	1.7E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	2.9	9.8E-2	9.7E-7	2.6

[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 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.
[d] Offsite.

Table D.3.2–22. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 1, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 577	2.7E-6	5.5E-11	2.2E-1	9.1E-6	1.9E-10	3.5E-1
INEL	153061 / 677	8.0E-7	9.9E-11	3.2E-1	2.7E-6	3.4E-10	5.8E-1
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LLNL	6324234 / 191	1.0E-2	1.6E-7	5.0E-2	3.4E-2	5.5E-7	8.9E-3
LANL	159152 / 653	2.1E-4	2.2E-8	2.8E-1	7.1E-4	7.5E-8	4.9E-1
ORNL	881652 / 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
Ports	639602 / 730	2.4E-10	3.1E-14	1.5E-1	8.3E-10	1.1E-13	1.6E-2
SNL-NM	610714 / 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 / 1986	1.9E-5	1.7E-10	6.6E-1	6.3E-5	5.9E-10	7.9E-1
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 / 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 / 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 / 501	3.2E-7	3.6E-11	1.1E-1	1.1E-6	1.2E-10	5.2E-3
Pantex	265185 / 446	8.3E-8	7.1E-12	9.8E-2	2.8E-7	2.4E-11	8.9E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
RFETS	2171877 / 298	3.6E-7	4.9E-12	7.1E-2	1.2E-6	1.7E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	2.9	9.8E-2	9.7E-7	2.5

[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 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.
[d] Offsite.

Table D.3.2–23. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 3, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 577	2.7E-6	5.5E-11	2.2E-1	9.1E-6	1.9E-10	3.5E-1
INEL	153061 / 677	8.0E-7	9.9E-11	3.2E-1	2.7E-6	3.4E-10	5.8E-1
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 / 653	2.1E-4	2.2E-8	2.8E-1	7.1E-4	7.5E-8	4.9E-1
NTS	14266 / 0	0.00	0.00	0.00	0.00	0.00	0.00
ORNL	881652 / 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL-NM	610714 / 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 / 1986	1.9E-5	1.7E-10	6.6E-1	6.3E-5	5.9E-10	7.9E-1
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 / 227	1.0E-2	1.6E-7	5.9E-2	3.4E-2	5.5E-7	8.9E-3
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 / 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 / 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 / 503	2.1E-8	2.3E-12	1.1E-1	7.1E-8	8.0E-12	5.2E-3
Pantex	265185 / 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 / 1075	1.8E-9	2.2E-13	2.3E-1	6.0E-9	7.5E-13	1.6E-2
RFETS	2171877 / 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	3.0	9.8E-2	9.7E-7	2.5

[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 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.
[d] Offsite.

Table D.3.2–24. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 6, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 577	2.7E-6	5.5E-11	2.2E-1	9.1E-6	1.9E-10	3.5E-1
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 / 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
ORNL	881652 / 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL-NM	610714 / 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 / 1986	1.9E-5	1.7E-10	6.6E-1	6.3E-5	5.9E-10	7.9E-1
INEL	153061 / 1032	1.3E-6	1.6E-10	4.3E-1	4.4E-6	5.4E-10	7.2E-1
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 / 227	1.0E-2	1.6E-7	5.9E-2	3.4E-2	5.5E-7	8.9E-3
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 / 867	1.1E-7	2.5E-12	1.9E-1	3.9E-7	8.6E-12	1.3E-2
Y-12	895379 / 1222	8.4E-8	3.1E-12	2.7E-1	2.9E-7	1.1E-11	1.9E-2
PGDP	500502 / 503	2.1E-8	2.3E-12	1.1E-1	7.1E-8	8.0E-12	5.2E-3
Pantex	265185 / 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 / 1075	1.8E-9	2.2E-13	2.3E-1	6.0E-9	7.5E-13	1.6E-2
RFETS	2171877 / 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	3.3	9.8E-2	9.7E-7	2.7

[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 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.
[d] Offsite.

Table D.3.2–25. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 7, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 843	4.2E-6	8.5E-11	2.9E-1	1.4E-5	2.9E-10	3.6E-1
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 / 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
NTS	14266 / 0	0.00	0.00	0.00	0.00	0.00	0.00
ORNL	881652 / 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL-NM	610714 / 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 / 1986	1.9E-5	1.7E-10	6.6E-1	6.3E-5	5.9E-10	7.9E-1
INEL	153061 / 1032	1.3E-6	1.6E-10	4.3E-1	4.4E-6	5.4E-10	7.2E-1
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 / 227	1.0E-2	1.6E-7	5.9E-2	3.4E-2	5.5E-7	8.9E-3
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 / 867	1.1E-7	2.5E-12	1.9E-1	3.9E-7	8.6E-12	1.3E-2
Y-12	895379 / 1222	8.4E-8	3.1E-12	2.7E-1	2.9E-7	1.1E-11	1.9E-2
PGDP	500502 / 503	2.1E-8	2.3E-12	1.1E-1	7.1E-8	8.0E-12	5.2E-3
Pantex	265185 / 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 / 1075	1.8E-9	2.2E-13	2.3E-1	6.0E-9	7.5E-13	1.6E-2
RFETS	2171877 / 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	3.4	9.8E-2	9.7E-7	2.7

[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 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.
[d] Offsite.

Table D.3.2-26. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 1, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 577	2.7E-6	5.5E-11	2.2E-1	9.1E-6	1.9E-10	3.5E-1
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 / 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
ORNL	881652 / 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL-NM	610714 / 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 / 2008	1.9E-5	1.8E-10	6.7E-1	6.3E-5	5.9E-10	8.0E-1
INEL	153061 / 1032	1.3E-6	1.6E-10	4.3E-1	4.4E-6	5.4E-10	7.2E-1
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 / 227	1.0E-2	1.6E-7	5.9E-2	3.4E-2	5.5E-7	8.9E-3
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 / 867	1.1E-7	2.5E-12	1.9E-1	3.9E-7	8.6E-12	1.3E-2
Y-12	895379 / 1222	8.4E-8	3.1E-12	2.7E-1	2.9E-7	1.1E-11	1.9E-2
PGDP	500502 / 503	2.1E-8	2.3E-12	1.1E-1	7.1E-8	8.0E-12	5.2E-3
Pantex	265185 / 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 / 1075	1.8E-9	2.2E-13	2.3E-1	6.0E-9	7.5E-13	1.6E-2
RFETS	2171877 / 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
TOTAL		2.9E-2	2.9E-7	3.3	9.8E-2	9.7E-7	2.7

[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 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.
[d] Offsite.

Table D.3.2–27. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 2, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 843	4.2E-6	8.5E-11	2.9E-1	1.4E-5	2.9E-10	3.6E-1
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 / 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
NTS	14266 / 0	0.00	0.00	0.00	0.00	0.00	0.00
ORNL	881652 / 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL-NM	610714 / 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 / 2008	1.9E-5	1.8E-10	6.7E-1	6.3E-5	5.9E-10	8.0E-1
INEL	153061 / 1032	1.3E-6	1.6E-10	4.3E-1	4.4E-6	5.4E-10	7.2E-1
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 / 227	1.0E-2	1.6E-7	5.9E-2	3.4E-2	5.5E-7	8.9E-3
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 / 867	1.1E-7	2.5E-12	1.9E-1	3.9E-7	8.6E-12	1.3E-2
Y-12	895379 / 1222	8.4E-8	3.1E-12	2.7E-1	2.9E-7	1.1E-11	1.9E-2
PGDP	500502 / 503	2.1E-8	2.3E-12	1.1E-1	7.1E-8	8.0E-12	5.2E-3
Pantex	265185 / 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 / 1075	1.8E-9	2.2E-13	2.3E-1	6.0E-9	7.5E-13	1.6E-2
RFETS	2171877 / 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	3.4	9.8E-2	9.7E-7	2.7

[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 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.
[d] Offsite.

Table D.3.2–28. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 2, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Fernald	2764589 / 461	2.3E-1	4.4E-6	1.2E-1	7.9E-1	1.5E-5	2.3E-2
Hanford	377645 / 1569	3.6E-6	7.3E-11	5.2E-1	1.2E-5	2.5E-10	6.9E-1
INEL	153061 / 1809	1.4E-6	1.7E-10	5.4E-1	4.6E-6	5.7E-10	5.8E-1
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LLNL	6324234 / 483	3.9E-1	6.3E-6	1.5E-1	1.3	2.1E-5	1.7E-1
LANL	159152 / 1362	7.8E-3	8.2E-7	4.9E-1	2.7E-2	2.8E-6	6.5E-1
ORNL	881652 / 4756	1.5E-5	4.6E-10	1.2	5.1E-5	1.6E-9	4.6E-1
Ports	639602 / 3434	5.3E-5	6.6E-9	7.4E-1	1.8E-4	2.2E-8	9.6E-2
SNL-NM	610714 / 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 / 2598	6.1E-4	5.7E-9	8.3E-1	2.1E-3	2.0E-8	9.6E-1
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
RFETS	2171877 / 800	1.9E-4	2.5E-9	2.2E-1	6.3E-4	8.6E-9	4.0E-3
K-25	871406 / 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 / 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Pantex	265185 / 1251	1.1E-7	9.1E-12	2.6E-1	3.7E-7	3.1E-11	9.5E-3
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
PGDP	500502 / 800	1.9E-6	2.1E-10	1.9E-1	6.4E-6	7.1E-10	5.8E-3
TOTAL		6.4E-1	6.3E-6	5.9	2.2	2.1E-5	3.8

[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 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.
[d] Offsite.

Table D.3.2–29. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 4, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 1634	4.7E-2	9.6E-7	5.4E-1	1.6E-1	3.3E-6	7.2E-1
INEL	153061 / 1809	1.4E-6	1.7E-10	5.4E-1	4.6E-6	5.7E-10	5.8E-1
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 / 2731	7.8E-3	8.2E-7	9.3E-1	2.7E-2	2.8E-6	1.2
ORNL	881652 / 4855	1.9E-5	5.7E-10	1.2	6.3E-5	1.9E-9	4.5E-1
Ports	639602 / 3483	1.9E-2	2.3E-6	7.6E-1	6.4E-2	7.9E-6	1.3E-1
SNL-NM	610714 / 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 / 2598	6.1E-4	5.7E-9	8.3E-1	2.1E-3	2.0E-8	9.6E-1
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 / 227	4.4E-3	7.1E-8	5.9E-2	1.5E-2	2.4E-7	8.9E-3
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
NTS	14266 / 0	0.00	0.00	0.00	0.00	0.00	0.00
K-25	871406 / 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 / 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 / 497	2.1E-8	2.4E-12	1.1E-1	7.2E-8	8.0E-12	5.2E-3
Pantex	265185 / 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
RFETS	2171877 / 800	1.9E-4	2.5E-9	2.2E-1	6.3E-4	8.6E-9	4.0E-3
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
TOTAL		9.7E-2	2.3E-6	6.1	3.3E-1	7.9E-6	4.3

[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 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.
[d] Offsite.

Table D.3.2-30. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternatives 3 and 4, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 1634	5.0E-2	1.0E-6	5.4E-1	1.7E-1	3.5E-6	7.2E-1
INEL	153061 / 1809	1.4E-6	1.7E-10	5.4E-1	4.6E-6	5.7E-10	5.8E-1
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 / 2731	7.8E-3	8.2E-7	9.3E-1	2.7E-2	2.8E-6	1.2
NTS	14266 / 0	0.00	0.00	0.00	0.00	0.00	0.00
ORNL	881652 / 4855	1.9E-5	5.7E-10	1.2	6.3E-5	1.9E-9	4.5E-1
Ports	639602 / 3481	1.9E-2	2.3E-6	7.6E-1	6.4E-2	7.9E-6	1.3E-1
SNL-NM	610714 / 232	1.8E-6	7.2E-11	7.7E-2	6.2E-6	2.4E-10	7.6E-2
SRS	620618 / 2598	6.1E-4	5.7E-9	8.3E-1	2.1E-3	2.0E-8	9.6E-1
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 / 227	4.4E-3	7.1E-8	5.9E-2	1.5E-2	2.4E-7	8.9E-3
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 / 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 / 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 / 497	2.1E-8	2.4E-12	1.1E-1	7.2E-8	8.0E-12	5.2E-3
Pantex	265185 / 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
RFETS	2171877 / 800	1.9E-4	2.5E-9	2.2E-1	6.3E-4	8.6E-9	4.0E-3
TOTAL		1.0E-1	2.3E-6	6.1	3.4E-1	7.9E-6	4.3

[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 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.
[d] Offsite.

Table D.3.2-31. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 5, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 1634	4.7E-2	9.6E-7	5.4E-1	1.6E-1	3.3E-6	7.2E-1
INEL	153061 / 3954	4.1E-4	5.1E-8	1.3	1.4E-3	1.7E-7	1.9
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 / 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
ORNL	881652 / 7524	4.6E-2	1.4E-6	1.8	1.6E-1	4.9E-6	5.6E-1
SNL-NM	610714 / 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 / 2598	6.1E-4	5.7E-9	8.3E-1	2.1E-3	2.0E-8	9.6E-1
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 / 227	4.4E-3	7.1E-8	5.9E-2	1.5E-2	2.4E-7	8.9E-3
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
NTS	14266 / 0	0.00	0.00	0.00	0.00	0.00	0.00
K-25	871406 / 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 / 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 / 497	2.1E-8	2.4E-12	1.1E-1	7.2E-8	8.0E-12	5.2E-3
Pantex	265185 / 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 / 1087	1.8E-9	2.2E-13	2.4E-1	5.9E-9	7.5E-13	1.6E-2
RFETS	2171877 / 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		1.2E-1	1.4E-6	6.2	4.0E-1	4.9E-6	4.8

[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 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.
[d] Offsite.

Table D.3.2–32. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 5, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 9856	7.5E-2	1.5E-6	3.7	2.5E-1	5.2E-6	5.3
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 / 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
SNL-NM	610714 / 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 / 1986	1.2E-5	1.2E-10	6.6E-1	4.2E-5	3.9E-10	7.9E-1
INEL	153061 / 677	8.0E-7	9.9E-11	3.2E-1	2.7E-6	3.4E-10	5.8E-1
ORNL	881652 / 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
LLNL	6324234 / 227	4.4E-3	7.1E-8	5.9E-2	1.5E-2	2.4E-7	8.9E-3
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 / 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 / 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 / 497	2.1E-8	2.4E-12	1.1E-1	7.2E-8	8.0E-12	5.2E-3
Pantex	265185 / 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 / 1087	1.8E-9	2.2E-13	2.4E-1	5.9E-9	7.5E-13	1.6E-2
RFETS	2171877 / 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		9.8E-2	1.5E-6	6.5	3.3E-1	5.2E-6	7.5

[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 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.
[d] Offsite.

Table D.3.2–33. Program-Wide Risks Associated with Disposal of LLW Under the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	1.2E1	
	Cancer Fatalities	5.7E-3	
	Cancer Incidence	2.0E-2	
	Genetic Effects	1.2E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	1.5E2	
	Cancer Fatalities	7.6E-2	
	Cancer Incidence	2.6E-1	
	Genetic Effects	1.5E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	7.4E3	
	Cancer Fatalities	3.0	
	Cancer Incidence	1.0E1	
	Genetic Effects	4.5E-1	
	Exposure Index		
	Construction Fatalities		1.7
	Construction Injuries		7.5E2
	Operation Fatalities		2.1
	Operation Injuries		1.8E3

Table D.3.2-34. Program-Wide Risks Associated with Disposal of LLW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	1.3E2	
	Cancer Fatalities	6.4E-2	
	Cancer Incidence	2.2E-1	
	Genetic Effects	1.3E-2	
	Hazard Index		
All Lifetimes	Dose (person-rem)	2.3E3	
	Cancer Fatalities	1.2	
	Cancer Incidence	4.0	
	Genetic Effects	2.3E-1	
	Hazard Index		
WM Workers	Dose (FTE-rem)	5.6E3	
	Cancer Fatalities	2.2	
	Cancer Incidence	7.9	
	Genetic Effects	3.4E-1	
	Exposure Index		
	Construction Fatalities		3.9
	Construction Injuries		1.7E3
	Operation Fatalities		1.8
	Operation Injuries		1.5E3

Table D.3.2–35. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	3.0	
	Cancer Fatalities	1.5E-3	
	Cancer Incidence	5.1E-3	
	Genetic Effects	3.0E-4	
	Hazard Index		
All Lifetimes	Dose (person-rem)	4.4E1	
	Cancer Fatalities	2.2E-2	
	Cancer Incidence	7.4E-2	
	Genetic Effects	4.4E-3	
	Hazard Index		
WM Workers	Dose (FTE-rem)	5.4E3	
	Cancer Fatalities	2.2	
	Cancer Incidence	7.6	
	Genetic Effects	3.2E-1	
	Exposure Index		
	Construction Fatalities		3.9
	Construction Injuries		1.7E3
	Operation Fatalities		1.8
	Operation Injuries		1.5E3

Table D.3.2–36. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	2.5	
	Cancer Fatalities	1.2E-3	
	Cancer Incidence	4.3E-3	
	Genetic Effects	2.5E-4	
	Hazard Index		
All Lifetimes	Dose (person-rem)	3.4E1	
	Cancer Fatalities	1.7E-2	
	Cancer Incidence	5.8E-2	
	Genetic Effects	3.4E-3	
	Hazard Index		
WM Workers	Dose (FTE-rem)	5.9E3	
	Cancer Fatalities	2.4	
	Cancer Incidence	8.3	
	Genetic Effects	3.5E-1	
	Exposure Index		
	Construction Fatalities		3.7
	Construction Injuries		1.6E3
	Operation Fatalities		1.6
	Operation Injuries		1.3E3

Table D.3.2–37. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 6, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	3.3E1	
	Cancer Fatalities	1.6E-2	
	Cancer Incidence	5.6E-2	
	Genetic Effects	3.3E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	4.3E2	
	Cancer Fatalities	2.2E-1	
	Cancer Incidence	7.3E-1	
	Genetic Effects	4.3E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.4E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.2	
	Genetic Effects	2.6E-1	
	Exposure Index		
	Construction Fatalities		5.1
	Construction Injuries		2.2E3
	Operation Fatalities		1.3
	Operation Injuries		1.1E3

Table D.3.2-38. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 7, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	3.4E-1	
	Cancer Fatalities	1.7E-4	
	Cancer Incidence	5.9E-4	
	Genetic Effects	3.4E-5	
	Hazard Index		
All Lifetimes	Dose (person-rem)	3.7	
	Cancer Fatalities	1.8E-3	
	Cancer Incidence	6.3E-3	
	Genetic Effects	3.7E-4	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.4E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.2	
	Genetic Effects	2.6E-1	
	Exposure Index		
	Construction Fatalities		5.0
	Construction Injuries		2.2E3
	Operation Fatalities		1.3
	Operation Injuries		1.1E3

Table D.3.2–39. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	9.6	
	Cancer Fatalities	4.8E-3	
	Cancer Incidence	1.6E-2	
	Genetic Effects	9.6E-4	
	Hazard Index		
All Lifetimes	Dose (person-rem)	1.3E2	
	Cancer Fatalities	6.4E-2	
	Cancer Incidence	2.2E-1	
	Genetic Effects	1.3E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	6.9E3	
	Cancer Fatalities	2.8	
	Cancer Incidence	9.7	
	Genetic Effects	4.2E-1	
	Exposure Index		
	Construction Fatalities		4.0E-1
	Construction Injuries		1.7E2
	Operation Fatalities		9.6E-1
	Operation Injuries		8.1E2

Table D.3.2–40. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-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)	6.9E3	
	Cancer Fatalities	2.8	
	Cancer Incidence	9.7	
	Genetic Effects	4.2E-1	
	Exposure Index		
	Construction Fatalities		3.7E-1
	Construction Injuries		1.6E2
	Operation Fatalities		9.6E-1
	Operation Injuries		8.1E2

Table D.3.2–41. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	1.0E1	
	Cancer Fatalities	5.2E-3	
	Cancer Incidence	1.8E-2	
	Genetic Effects	1.0E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	1.5E2	
	Cancer Fatalities	7.2E-2	
	Cancer Incidence	2.5E-1	
	Genetic Effects	1.5E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.5E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.3	
	Genetic Effects	2.7E-1	
	Exposure Index		
	Construction Fatalities		3.0
	Construction Injuries		1.3E3
	Operation Fatalities		1.2
	Operation Injuries		1.0E3

Table D.3.2–42. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	2.8E1	
	Cancer Fatalities	1.4E-2	
	Cancer Incidence	4.8E-2	
	Genetic Effects	2.8E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	3.7E2	
	Cancer Fatalities	1.9E-1	
	Cancer Incidence	6.3E-1	
	Genetic Effects	3.7E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.5E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.3	
	Genetic Effects	2.7E-1	
	Exposure Index		
	Construction Fatalities		2.8
	Construction Injuries		1.2E3
	Operation Fatalities		1.1
	Operation Injuries		9.0E2

Table D.3.2–43. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	1.8E1	
	Cancer Fatalities	9.2E-3	
	Cancer Incidence	3.1E-2	
	Genetic Effects	1.8E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	2.5E2	
	Cancer Fatalities	1.2E-1	
	Cancer Incidence	4.2E-1	
	Genetic Effects	2.5E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.4E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.2	
	Genetic Effects	2.7E-1	
	Exposure Index		
	Construction Fatalities		2.5E-1
	Construction Injuries		1.1E2
	Operation Fatalities		6.3E-1
	Operation Injuries		5.4E2

Table D.3.2–44. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-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)	4.4E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.2	
	Genetic Effects	2.7E-1	
	Exposure Index		
	Construction Fatalities		2.2E-1
	Construction Injuries		9.6E1
	Operation Fatalities		6.3E-1
	Operation Injuries		5.4E2

Table D.3.2–45. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	2.8E1	
	Cancer Fatalities	1.4E-2	
	Cancer Incidence	4.8E-2	
	Genetic Effects	2.8E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	3.7E2	
	Cancer Fatalities	1.8E-1	
	Cancer Incidence	6.3E-1	
	Genetic Effects	3.7E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.5E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.3	
	Genetic Effects	2.7E-1	
	Exposure Index		
	Construction Fatalities		2.8
	Construction Injuries		1.2E3
	Operation Fatalities		1.1
	Operation Injuries		9.0E2

Table D.3.2–46. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	1.8E1	
	Cancer Fatalities	9.2E-3	
	Cancer Incidence	3.1E-2	
	Genetic Effects	1.8E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	2.5E2	
	Cancer Fatalities	1.2E-1	
	Cancer Incidence	4.2E-1	
	Genetic Effects	2.5E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.4E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.2	
	Genetic Effects	2.6E-1	
	Exposure Index		
	Construction Fatalities		2.5E-1
	Construction Injuries		1.1E2
	Operation Fatalities		6.3E-1
	Operation Injuries		5.3E2

Table D.3.2–47. Program-Wide Risks Associated with Disposal of LLW Under the No Action Alternative, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-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	4.9E-1	0.00	0.00	2.8E-1
SRS (153)	1.5E-4	2.2E-3	2.8	5.0E-4	7.3E-3	2.5
ORR 225)	8.2E-8	1.2E-6	3.5E-1	2.8E-7	4.0E-6	1.3E-1
Hanford (18)	5.6E-3	8E-2	1.1	1.9E-2	2.7E-1	2.3
INEL (0)	0.00	0.00	8.5E-1	0.00	0.00	2.2
TOTAL	5.7E-3	7.6E-2	6.8	2.0E-2	2.6E-1	1.0E1

[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. Program-Wide Risks Associated with Disposal of LLW Under the Decentralized Alternative, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
INEL (0)	0.00	0.00	6.6E-1	0.00	0.00	1.5
LLNL (142)	4.4E-6	6.8E-5	2.3E-1	1.5E-5	2.3E-4	5.6E-1
LANL (0)	0.00	0.00	8.8E-1	0.00	0.00	2.0
ORR (22)	1.0E-7	1.4E-5	4.6E-1	3.4E-6	4.6E-5	1.0E-1
SNL-NM (15)	6.3E-2	1.1	9.5E-2	2.1E-1	3.9	2.2E-1
PGDP (42)	3.7E-4	6.1E-3	1.5E-1	1.3E-3	2.1E-2	1.1E-2
Pantex (0)	0.00	0.00	1.4E-1	0.00	0.00	9.8E-3
RFETS (38)	1.1E-7	2.1E-6	1.4E-1	3.7E-7	7.0E-6	9.9E-3
SRS (153)	1.1E-4	1.7E-3	4.1	3.8E-4	5.6E-3	2.0
Ports (37)	2.4E-7	4.5E-6	4.4E-1	8.2E-7	1.5E-5	4.6E-2
ANL-E (64)	1.1E-4	5.1E-3	1.1E-1	3.9E-4	1.7E-2	1.5E-1
Hanford (18)	1.0E-3	1.4E-2	5.6E-1	3.4E-3	4.7E-2	1.3
TOTAL	6.4E-2	1.2	7.9	2.2E-1	3.9	7.9

[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.3.2–49. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 1, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.0E-3	1.4E-2	5.6E-1	3.4E-3	4.7E-2	1.3
INEL (0)	0.00	0.00	6.6E-1	0.00	0.00	1.5
LLNL (142)	4.4E-6	6.8E-5	2.3E-1	1.5E-5	2.3E-4	5.6E-1
LANL (0)	0.00	0.00	8.9E-1	0.00	0.00	2.0
ORR (22)	1.0E-7	1.4E-5	4.6E-1	3.4E-6	4.6E-5	1.0E-1
Ports (145)	2.0E-6	7.7E-5	5.2E-1	6.9E-6	2.6E-4	1.1E-1
PGDP (42)	3.7E-4	6.1E-3	1.5E-1	1.3E-3	2.1E-2	1.1E-2
Pantex (0)	0.00	0.00	1.4E-1	0.00	0.00	9.8E-3
SRS (153)	1.2E-4	1.8E-3	4.1	4.1E-4	6.0E-3	2.0
RFETS (38)	1.1E-7	2.1E-6	1.4E-1	3.7E-7	7.0E-6	9.9E-3
TOTAL	1.5E-3	2.2E-2	7.8	5.1E-3	7.4E-2	7.6

[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. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 3, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.0E-3	1.4E-2	5.6E-1	3.4E-3	4.7E-2	1.3
INEL (0)	0.00	0.00	6.6E-1	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	2.3E-1	0.00	0.00	5.7E-1
ORR (22)	1.2E-4	1.5E-3	8.8E-1	4.2E-4	5.2E-3	1.8E-1
SRS (153)	1.2E-4	1.8E-3	4.1	4.1E-4	6.0E-3	2.0
TOTAL	1.3E-3	1.7E-2	7.6	4.3E-3	5.8E-2	8.3

[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. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 6, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.6E-2	2.2E-1	1.8	5.5E-2	7.3E-1	4.0
SRS (23)	1.7E-4	1.9E-3	6.4	5.9E-4	6.6E-3	2.1
TOTAL	1.6E-2	2.2E-1	8.2	5.6E-2	7.4E-1	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. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 7, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	1.7	0.00	0.00	4.1
SRS (23)	1.7E-4	1.9E-3	6.4	5.9E-4	6.3E-3	2.1
TOTAL	1.7E-4	1.9E-3	8.1	5.9E-4	6.3E-3	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.3.2–53. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 1, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	4.8E-3	6.4E-2	4.1	1.6E-2	2.2E-1	9.7
TOTAL	4.8E-3	6.4E-2	4.1	1.6E-2	2.2E-1	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. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 2, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	4.1	0.00	0.00	9.7
TOTAL	0.00	0.00	4.1	0.00	0.00	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.3.2–55. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 2, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	4.5E-3	6.2E-2	4.3E-1	1.5E-2	2.1E-1	1,1
INEL (0)	0.00	0.00	4.9E-1	0.00	0.00	1.2
LLNL (142)	4.4E-6	6.8E-5	1.9E-1	1.5E-5	2.3E-4	4.7E-1
LANL (0)	0.00	0.00	5.3E-1	0.00	0.00	1.3
ORR (22)	4.6E-6	6.3E-5	2.0E-1	1.6E-5	2.1E-4	1.7E-1
Ports (145)	3.5E-6	1.3E-4	3.2E-1	1.2E-5	4.5E-4	9.3E-2
PGDP (42)	5.0E-4	8.1E-3	1.3E-1	1.7E-3	2.8E-2	9.7E-3
Pantex (0)	0.00	0.00	6.3E-2	0.00	0.00	4.7E-3
SRS (153)	1.4E-4	2.1E-3	3.5	4.9E-4	7.2E-3	2.0
RFETS (38)	3.2E-7	6.2E-6	6.8E-2	1.1E-6	2.1E-5	5.6E-3
TOTAL	5.2E-3	7.2E-2	6.0	18E-2	2.5E-1	6.3

[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. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 4, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
LANL (0	0.00	0.00	5.7E-1	0.00	0.00	1.4
ORR (22)	2.8E-4	3.6E-3	4.7E-1	9.6E-4	1.2E-2	1.7E-1
NTS (0)	0.00	0.00	1.6E-1	0.00	0.00	3.9E-1
SRS (153)	1.4E-4	2.1E-3	3.5	4.9E-4	7.2E-3	2.0
INEL (0)	0.00	0.00	5.2E-1	0.00	0.00	1.3
Hanford (18)	1.4E-2	1.8E-1	4.3E-1	4.6E-2	6.1E-1	1.1
TOTAL	1.4E-2	1.9E-1	5.7	4.8E-2	6.3E-1	6.3

[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. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 3, By Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	9.2E-3	1.2E-1	2.7	3.1E-2	4.2E-1	6.2
TOTAL	9.2E-3	1.2E-1	2.7	3.1E-2	4.2E-1	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. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 4, By Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	2.6	0.00	0.00	6.2
TOTAL	0.00	0.00	2.6	0.00	0.00	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.3.2–59. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 5, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.4E-2	1.8E-1	4.3E-1	4.6E-2	6.1E-1	1.1
LANL (0)	0.00	0.00	5.9E-1	0.00	0.00	1.4
ORR (22)	2.8E-4	3.5E-3	4.7E-1	9.6E-4	1.2E-2	1.7E-1
NTS (0)	0.00	0.00	1.6E-1	0.00	0.00	3.9E-1
SRS (153)	1.4E-4	2.1E-3	3.5	4.9E-4	7.2E-3	2.0
INEL (0)	0.00	0.00	4.9E-1	0.00	0.00	1.2
TOTAL	1.4E-2	1.9E-1	5.7	4.8E-2	6.3E-1	6.3

[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. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 5, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	9.2E-3	1.2E-1	2.6	3.1E-2	4.2E-1	6.2
TOTAL	9.2E-3	1.2E-1	2.6	3.1E-2	4.2E-1	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.3.2.6 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.3.2.7 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 intra-facility source term for this accident is, therefore, 1000 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).

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 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 1E-2); the baghouse area facility fire is considered "unlikely" (1E-4 to 1E-2); the earthquake resulting in an incinerator facility fire is considered "very unlikely" (1E-6 to 1E-4); and the aircraft impact is regarded as "extremely unlikely" (less than 1E-6) (see Appendix F).

D.3.2.8 Results Tables for the Risk Analysis of Potential LLW Accidents

Table D.3.2–61 presents a summary of the worst-case 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 Worst-Case LLW Treatment Facility Accidents, by Alternative and Installation

Installation	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
No Action										
INEL	5.9E-5	2.0E-4	6.7E-9	2.3E-8	2.2E-5	7.5E-5	1.3E-8	4.5E-8	1.5E-5	5.4E-5
SRS	4.6E-2	1.6E-1	1.4E-6	4.9E-6	9.6E-3	3.3E-2	4.2E-5	1.4E-4	9.5E-3	3.3E-2
Regionalized 2										
FEMP	6.0E-5	2.1E-4	1.6E-8	5.4E-8	2.2E-6	7.6E-6	1.5E-8	5.1E-8	3.6E-7	1.3E-6
Hanford	2.4E-3	8.1E-3	5.5E-8	1.9E-7	1.2E-4	4.2E-4	1.3E-6	4.2E-6	1.0E-5	3.5E-5
INEL	5.9E-5	2.0E-4	6.7E-9	2.3E-8	2.2E-5	7.5E-5	1.3E-8	4.5E-8	1.9E-5	6.7E-5
LANL	8.7E-1	3.0	4.1E-4	1.4E-3	2.5E-1	8.6E-1	7.4E-4	2.5E-3	2.5E-1	8.7E-1
LLNL	2.9	9.8	4.0E-4	1.4E-3	2.1E-1	7.1E-1	3.6E-4	1.2E-3	7.3E-3	2.6E-2
ORR	1.1E-2	3.9E-2	9.7E-7	3.3E-6	8.2E-3	2.8E-2	9.1E-6	3.1E-5	2.5E-4	8.6E-4
PGDP	2.5E-4	8.6E-4	7.4E-8	2.5E-7	4.9E-5	1.7E-4	4.3E-7	1.5E-6	3.8E-5	1.3E-4
Ports	2.5E-5	8.6E-5	1.7E-8	5.9E-8	1.1E-5	3.8E-5	1.7E-8	5.7E-8	5.2E-6	1.8E-5
RFETS	2.8E-2	9.4E-2	9.8E-7	3.3E-6	4.8E-3	1.6E-2	1.4E-5	4.8E-5	2.1E-3	7.3E-3
SRS	4.6E-2	1.6E-1	1.4E-6	4.9E-6	9.6E-3	3.3E-2	4.2E-5	1.4E-4	1.2E-2	4.1E-2
Centralized 5										
Hanford	4.8	1.6E1	1.1E-4	3.8E-4	9.1E-1	3.1	9.2E-3	3.1E-2	6.0E-1	2.1

[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.3.2-62. Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Potential LLW Treatment Accidents, by Installation

Installation	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		2	
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]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake (VU)[c]	3.9E-5	4.5E-9	1.0E-5	1.3E-4	1.5E-8	3.6E-5
Incineration, Incinerator Explosion (A)	2.4E-8	2.7E-12	6.1E-6	8.0E-8	9.1E-12	2.2E-5
Incineration, Baghouse Facility Fire (U)	5.9E-7	6.7E-11	1.5E-7	2.0E-6	2.3E-10	5.4E-7
Incineration, Large Aircraft Crash (EU)	5.9E-5	6.7E-9	1.5E-5	2.0E-4	2.3E-8	5.4E-5
WORST-CASE ACCIDENT	5.9E-5	6.7E-9	1.5E-5	2.0E-4	2.3E-8	5.4E-5

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

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]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Large Aircraft Crash (EU)[c]	4.6E-2	1.4E-6	9.5E-3	1.6E-1	4.9E-6	3.3E-2
Incineration, Earthquake (VU)	3.1E-2	9.6E-7	6.3E-3	1.0E-1	3.3E-6	2.2E-2
Incineration, Incinerator Explosion (A)	1.8E-5	5.8E-10	3.8E-3	6.2E-5	2.0E-9	1.3E-2
Incineration, Baghouse Facility Fire (U)	4.6E-4	1.4E-8	9.5E-5	1.6E-3	4.9E-8	3.3E-4
WORST-CASE ACCIDENT	4.6E-2	1.4E-6	9.5E-3	1.6E-1	4.9E-6	3.3E-2

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

Table D.3.2-65. Accident Risks Associated With LLW Treatment at FEMP Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake (VU)[c]	6.0E-5	1.6E-8	3.6E-7	2.1E-4	5.4E-8	1.3E-6
Incineration, Incinerator Explosion (A)	3.6E-8	9.5E-12	2.1E-7	1.2E-7	3.2E-11	7.5E-7
Incineration, Baghouse Facility Fire (U)	9.1E-7	2.4E-10	5.4E-9	3.1E-6	8.1E-10	1.9E-8
WORST-CASE ACCIDENT	6.0E-5	1.6E-8	3.6E-7	2.1E-4	5.4E-8	1.3E-6

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

Table D.3.2-66. Accident Risks Associated With LLW Treatment at Hanford Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake (VU)[c]	1.6E-3	3.7E-8	6.7E-6	5.4E-3	1.3E-7	2.3E-5
Incineration, Incinerator Explosion (A)	9.5E-7	2.2E-11	4.0E-6	3.2E-6	7.5E-11	1.4E-5
Incineration, Baghouse Facility Fire (U)	2.4E-5	5.5E-10	1.0E-7	8.1E-5	1.9E-9	3.5E-7
Incineration, Large Aircraft Crash (EU)	2.4E-3	5.5E-8	1.0E-5	8.1E-3	1.9E-7	3.5E-5
WORST-CASE ACCIDENT	2.4E-3	5.5E-8	1.0E-5	8.1E-3	1.9E-7	3.5E-5

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

Table D.3.2-67. Accident Risks Associated With LLW Treatment at INEL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Large Aircraft Crash (EU)[c]	5.9E-5	6.7E-9	1.9E-5	2.0E-4	2.3E-8	6.7E-5
Incineration, Earthquake (VU)	3.9E-5	4.5E-9	1.3E-5	1.3E-4	1.5E-8	4.5E-5
Incineration, Incinerator Explosion (A)	2.4E-8	2.7E-12	7.7E-6	8.0E-8	9.1E-12	2.7E-5
Incineration, Baghouse Facility Fire (U)	5.9E-7	6.7E-11	1.9E-7	2.0E-6	2.3E-10	6.7E-7
WORST-CASE ACCIDENT	5.9E-5	6.7E-9	1.9E-5	2.0E-4	2.3E-8	6.7E-5

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

Table D.3.2-68. Accident Risks Associated With LLW Treatment at LLNL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake (VU)[c]	2.9	4.0E-4	7.3E-3	9.8	1.4E-3	2.6E-2
Incineration, Incinerator Explosion (A)	1.7E-3	2.4E-7	4.4E-3	5.9E-3	8.1E-7	1.5E-2
Incineration, Baghouse Facility Fire (U)	4.3E-2	6.0E-6	1.1E-4	1.5E-1	2.0E-5	3.8E-4
WORST-CASE ACCIDENT	2.9	4.0E-4	7.3E-3	9.8	1.4E-3	2.6E-2

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

Table D.3.2-69. Accident Risks Associated With LLW Treatment at LANL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake (VU)[c]	8.7E-1	4.1E-4	2.5E-1	3.0	1.4E-3	8.7E-1
Incineration, Incinerator Explosion (A)	5.2E-4	2.5E-7	1.5E-1	1.8E-3	8.4E-7	5.2E-1
Incineration, Baghouse Facility Fire (U)	1.3E-2	6.2E-6	3.7E-3	4.4E-2	2.1E-5	1.3E-2
WORST-CASE ACCIDENT	8.7E-1	4.1E-4	2.5E-1	3.0	1.4E-3	8.7E-1

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

Table D.3.2-70. Accident Risks Associated With LLW Treatment at ORR Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake (VU)[c]	1.1E-2	9.7E-7	2.5E-4	3.9E-2	3.3E-6	8.6E-4
Incineration, Incinerator Explosion (A)	6.9E-6	5.8E-10	1.5E-4	2.3E-5	2.0E-9	5.2E-4
Incineration, Baghouse Facility Fire (U)	1.7E-4	1.5E-8	3.7E-6	5.8E-4	4.9E-8	1.3E-5
WORST-CASE ACCIDENT	1.1E-2	9.7E-7	2.5E-4	3.9E-2	3.3E-6	8.6E-4

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

Table D.3.2–71. Accident Risks Associated With LLW Treatment at PGDP Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake (VU)[c]	2.5E-4	7.4E-8	3.8E-5	8.6E-4	2.5E-7	1.3E-4
Incineration, Incinerator Explosion (A)	1.5E-7	4.4E-11	2.3E-5	5.2E-7	1.5E-10	7.9E-5
Incineration, Baghouse Facility Fire (U)	3.8E-6	1.1E-9	5.6E-7	1.3E-5	3.8E-9	2.0E-6
Incineration, Small Aircraft Crash (EU)	6.3E-5	1.8E-8	9.4E-6	2.2E-4	6.3E-8	3.3E-5
WORST-CASE ACCIDENT	2.5E-4	7.4E-8	3.8E-5	8.6E-4	2.5E-7	1.3E-4

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

Table D.3.2–72. Accident Risks Associated With LLW Treatment at Ports Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Baghouse Facility Fire (U)[c]	3.8E-7	2.6E-10	7.8E-8	1.3E-6	8.8E-10	2.7E-7
Incineration, Earthquake (VU)	2.5E-5	1.7E-8	5.2E-6	8.6E-5	5.9E-8	1.8E-5
Incineration, Incinerator Explosion (A)	1.5E-8	1.0E-11	3.1E-6	5.1E-8	3.5E-11	1.1E-5
WORST-CASE ACCIDENT	2.5E-5	1.7E-8	5.2E-6	8.6E-5	5.9E-8	1.8E-5

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

Table D.3.2–73. Accident Risks Associated With LLW Treatment at RFETS Under the Regionalized Alternative 2, by Accident Type

Accident		Cancer Fatalities[a]			Cancer Incidence[a]		
		Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Small Aircraft Crash (alpha)	(EU)[c]	6.9E-3	2.5E-7	5.2E-4	2.4E-2	8.3E-7	1.8E-3
Incineration, Baghouse Facility Fire (alpha)	(U)	4.2E-4	1.5E-8	3.1E-5	1.4E-3	5.0E-8	1.1E-4
Incineration, Earthquake (alpha)	(VU)	2.8E-2	9.8E-7	2.1E-3	9.4E-2	3.3E-6	7.3E-3
Incineration, Incinerator Explosion (alpha)	(A)	1.7E-5	5.9E-10	1.3E-3	5.7E-5	2.0E-9	4.4E-3
WORST-CASE ACCIDENT		2.8E-2	9.8E-7	2.1E-3	9.4E-2	3.3E-6	7.3E-3

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

Table D.3.2–74. Accident Risks Associated With LLW Treatment at SRS Under the Regionalized Alternative 2, by Accident Type

Accident		Cancer Fatalities[a]			Cancer Incidence[a]		
		Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Large Aircraft Crash	(EU)[c]	4.6E-2	1.4E-6	1.2E-2	1.6E-1	4.9E-6	4.1E-2
Incineration, Earthquake	(VU)	3.1E-2	9.6E-7	7.9E-3	1.0E-1	3.3E-6	2.8E-2
Incineration, Incinerator Explosion	(A)	1.8E-5	5.8E-10	4.7E-3	6.2E-5	2.0E-9	1.7E-2
Incineration, Baghouse Facility Fire	(U)	4.6E-4	1.4E-8	1.2E-4	1.6E-3	4.9E-8	4.1E-4
WORST-CASE ACCIDENT		4.6E-2	1.4E-6	1.2E-2	1.6E-1	4.9E-6	4.1E-2

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[a] Offsite.
[c] 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-6).

Table D.3.2–75. Accident Risks Associated With LLW Treatment at Hanford Under the Centralized Alternative 5, by Accident Type

Accident		Cancer Fatalities[a]			Cancer Incidence[a]		
		Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Large Aircraft Crash (non-alpha)	(EU)[c]	4.8	1.1E-4	6.0E-1	1.6E1	3.8E-4	2.1
Incineration, Large Aircraft Crash (alpha)	(EU)	2.4E-2	5.6E-7	3.1E-3	8.0E-2	1.9E-6	1.1E-2
Incineration, Earthquake (non-alpha)	(VU)	3.2	7.5E-5	4.0E-1	1.1E1	2.5E-4	1.4
Incineration, Earthquake (alpha)	(VU)	1.6E-2	3.7E-7	2.1E-3	5.4E-2	1.3E-6	7.3E-3
Incineration, Incinerator Explosion (non-alpha)	(A)	1.9E-3	4.5E-8	2.4E-1	6.5E-3	1.5E-7	8.5E-1
Incineration, Incinerator Explosion (alpha)	(A)	9.5E-6	2.2E-10	1.3E-3	3.2E-5	7.6E-10	4.4E-3
Incineration, Baghouse Facility Fire (non-alpha)	(U)	4.8E-2	1.1E-6	6.0E-3	1.6E-1	3.8E-6	2.1E-2
Incineration, Baghouse Facility Fire (alpha)	(U)	2.4E-4	5.6E-9	3.1E-5	8.0E-4	1.9E-8	1.1E-4
WORST-CASE ACCIDENT		4.8	1.1E-4	6.0E-1	1.6E1	3.8E-4	2.1

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] 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-6).

D.3.2.9 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 (non-alpha). 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 non-alpha 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.

D.3.2.9.1 *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-8 cancer fatalities) and for the same accident at FEMP (3.4E-8 cancer fatalities) and Ports (1.5E-8 cancer fatalities) in Regionalized 2. The highest accident risks are at Hanford in Centralized 5 for the large airplane crash during incineration (4.8 cancer fatalities) and for the earthquake during incineration (3.2 cancer fatalities) and at LLNL and LANL in Regionalized 2 for the earthquake during incineration (2.9 and 8.7E-1 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 worst-case 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 resulting in a fire are the worst-case accidents in all alternatives and vary by less than 1 order of magnitude at all installations 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 1E-6) and an earthquake is considered "very unlikely" (1E-6 to 1E-4).

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.3.2.9.2 *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 installations are the same as for offsite population.

D.3.2.9.3 *Risks to the Most-Exposed Noninvolved Worker and Most-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 worst-case cancer fatality risks are at Hanford in Centralized 5 (9.2E-3) and at LLNL and LANL in Regionalized 2 (3.6E-4 and 7.4E-4, respectively). The highest cancer fatality risks to the offsite MEI are at LLNL and LANL in Regionalized 2 (4.0E-4 and 4.1E-4, respectively) and at Hanford in Centralized 5 (1.1E-4). 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 installations (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 installations 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 installations.

D.3.2.9.4 *Risks to Waste Management Workers from LLW Accidents*

The cancer fatality risks to workers from worst-case accidents range from 3.6E-7 to 6.0E-1; 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 1E-6); the earthquake scenario is considered "very unlikely" (1E-6 to 1E-4); the baghouse fire is considered "unlikely" (1E-4 to 1E-2); and the incinerator explosion is "anticipated" (greater than 1E-2).

The highest worker cancer fatality risk is for the worst-case 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 installations in No Action and Regionalized 2 are SRS and LANL (Regionalized 2 only). Worker cancer fatality risks at the other installations 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.3.2.10 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-2	2.7E-1	1.6E-2
Regionalized 3	110	5.3E-2	1.8E-1	1.1E-2
Centralized 1	1.7	8.3E-3	2.8E-2	1.7E-3

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-4	2.8E-3	1.7E-4
Regionalized 3	1.1	5.7E-4	1.9E-3	1.1E-4
Centralized 1	1.7E-1	8.4E-5	2.9E-4	1.7E-5

Table D.3.2-78. Intruder Scenario Risk Results for the Decentralized Alternative (100 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
ANL-E	6.6E-1	3.3E-4	1.1E-3	6.6E-5
Hanford	6.8	3.4E-3	1.2E-2	6.8E-4
INEL	7.0E-1	3.5E-4	1.2E-3	7.0E-5
LANL	142	7.1E-2	2.4E-1	1.4E-2
LLNL	5.8	2.9E-3	9.8E-3	5.8E-4
ORR	1.3	6.6E-4	2.2E-3	1.3E-4
PGDP	6.7E-3	3.3E-6	1.1E-5	6.7E-7
Pantex	5.2E-3	2.6E-6	8.9E-6	5.2E-7
PORTS	4.8E-1	2.4E-4	8.2E-4	4.8E-5
RFETS	2.4E-3	1.2E-6	4.1E-6	2.4E-7
SNL-NM	1.5	7.3E-4	2.5E-3	1.5E-4
SRS	2.3	1.2E-3	4.0E-3	2.3E-4
TOTAL	160	8.0E-2	2.7E-1	1.6E-2

Table D.3.2-79. Intruder Scenario Risk Results for the Decentralized Alternative (300 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
ANL-E	7.6E-3	3.8E-6	1.3E-5	7.6E-7
Hanford	5.8E-2	2.9E-5	9.9E-5	5.8E-6
INEL	1.3E-1	6.6E-5	2.2E-4	1.3E-5
LANL	1.2	5.9E-4	2.0E-3	1.2E-4
LLNL	1.0E-1	5.0E-5	1.7E-4	1.0E-5
ORR	1.1E-2	5.3E-6	1.8E-5	1.1E-6
PGDP	6.6E-3	3.3E-6	1.1E-5	6.6E-7
Pantex	5.2E-3	2.6E-6	8.9E-6	5.2E-7
PORTS	1.2E-1	6.0E-5	2.0E-4	1.2E-5
RFETS	1.9E-3	9.5E-7	3.2E-6	1.9E-7
SNL-NM	2.6E-2	1.3E-5	4.4E-5	2.6E-6
SRS	2.6E-2	1.3E-5	4.5E-5	2.6E-6
TOTAL	1.7	8.4E-4	2.8E-3	1.7E-4

Table D.3.2–80. Intruder Scenario Risk Results for the Regionalized Alternative 3 (100 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	6.8	3.4E-3	1.2E-2	6.8E-4
INEL	7.0E-1	3.5E-4	1.2E-3	7.0E-5
LANL	91	4.5E-2	1.5E-1	9.1E-3
NTS	5.8	2.9E-3	9.8E-3	5.8E-4
ORR	8.1E-1	4.1E-4	1.4E-3	8.1E-5
SRS	2.3	1.2E-3	4.0E-3	2.3E-4
TOTAL	110	5.3E-2	1.8E-1	1.1E-2

Table D.3.2–81. Intruder Scenario Risk Results for the Regionalized Alternative 3 (300 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	5.8E-2	2.9E-5	9.9E-5	5.8E-6
INEL	1.3E-1	6.6E-5	2.2E-4	1.3E-5
LANL	7.6E-1	3.8E-4	1.3E-3	7.6E-5
NTS	1.0E-1	5.0E-5	1.7E-4	1.0E-5
ORR	6.1E-2	3.0E-5	1.0E-4	6.1E-6
SRS	2.6E-2	1.3E-5	4.5E-5	2.6E-6
TOTAL	1.1	5.7E-4	1.9E-3	1.1E-4

Table D.3.2-82. Intruder Scenario Risk Results for the Centralized Alternative 1 (100 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	1.7	8.3E-3	2.8E-2	1.7E-3
TOTAL	1.7	8.3E-3	2.8E-2	1.7E-3

Table D.3.2-83. Intruder Scenario Risk Results for the Centralized Alternative 1 (300 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	1.7E-1	8.4E-5	2.9E-4	1.7E-5
TOTAL	1.7E-1	8.4E-5	2.9E-4	1.7E-5

D.3.2.10.1 Results of the Human Health Risk Analysis for the Intruder

In the Decentralized Alternative, LLW is disposed of at 12 installations. One hundred years after the end of disposal operations, the highest intruder cancer fatality risk is at LANL (7.1E-2). This is due to both the large volume of waste disposed at LANL in this alternative and the presence of Sr-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-6), which disposes only of 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-4) and RFETS (9.5E-7), respectively; Sr-90 continues to be the driving contaminant at LANL.

In the Regionalized Alternative 3, LLW is consolidated and disposed of at six installations. One hundred years after the completion of disposal operations, the highest intruder cancer fatality risk is at LANL (4.5E-2). Again, this is due to the large volume of waste disposed and the presence of Sr-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-4), which disposes only of its own waste. Three hundred

years after the end of disposal operations, the highest intruder cancer fatality risk remains at LANL (3.8E-4). The lowest intruder cancer fatality risk is at SRS (1.3E-5), 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-3. 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 installations 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 non-specific 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 installations 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 installations 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, 1995d). 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 installations, 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, 1995d).

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 and disposed of by permitted commercial facilities.
- In the Regionalized Alternative 1, approximately 50% of the complex-wide, 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 complex-wide, 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.

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 installations; remainder treated commercially				T[a]				T			
Regionalized 1—50% of DOE HW treated (by incineration and fuel burning) at 5 installations; remainder treated commercially		T		T		T		T			T
Regionalized 2—80-90% of DOE HW treated (by incineration and fuel burning) at 2 installations; remainder treated commercially				T				T			

[a] T—Treatment installation

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, 1995d). The results of those burns were scaled up based on each installation's HW waste volume.

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)

It was assumed that the composition of HW and the relative proportions of its components are the same at all installations. Because of this, the controlling contaminants and their percentage contribution to risk are the same across all installations and alternatives.

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 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 dibenzodioxins 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 bromodichloromethane, 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-5% of the source term, and the fourth is 3E-6% 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*, program-wide 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 program-wide 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 Program-Wide Risks Associated with Routine Management of HW: Risks to Total Populations, By Alternative

Alternative	Offsite Population	WM Workers		Noninvolved Worker Population
	Chem CI[a]	Chem CI	C&OF[b]	Chem CI
No Action	7.5E-3	9.4E-2	8.2E-3	2.5E-3
Regionalized 1	6.0E-2	1.2	6.9E-2	2.5E-2
Regionalized 2	9.6E-2	1.8	7.3E-2	3.3E-2

[a] Chem CI—cancer incidence associated with exposure to hazardous chemicals.
[b] 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 Program-Wide Risks Associated with Managing HW to the Offsite and Noninvolved Worker Most-Exposed Individuals, By Alternative

Alternative	Offsite MEI[a]		Noninvolved Worker MEI	
	Chem CI[b]	HI[c]	Chem CI	HI
No Action	3.9E-7	2.6E-3	2.4E-6	1.6E-2
Regionalized 1	2.4E-6	3.2E-2	1.1E-5	5.1E-1
Regionalized 2	5.0E-6	6.6E-2	3.1E-5	4.1E-1

[a] MEI—Most-exposed individual
[b] Chem CI—cancer incidence associated with exposure to hazardous chemicals
[c] HI—Hazard index

Table D.3.3-6 Program-Wide 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-3		
	Genetic Effects			
Noninvolved Worker MEI	Dose (rem)			
	Cancer Fatalities			
	Cancer Incidence	2.4E-6		
	Genetic Effects			
	Hazard Index		1.6E-2	
Offsite Population	Dose (person-rem)			
	Cancer Fatalities			
	Cancer Incidence	7.5E-3		
	Genetic Effects			
Offsite MEI	Dose (rem)			
	Cancer Fatalities			
	Cancer Incidence	3.9E-7		
	Genetic Effects			
	Hazard Index		2.6E-3	
WM Workers	Dose (FTE-rem)			
	Cancer Fatalities			
	Cancer Incidence	9.4E-2		
	Genetic Effects			
	Exposure Index		4.3	
	Construction Fatalities			1.9E-3
	Construction Injuries			8.4E-1
	Operation Fatalities			6.3E-3
	Operation Injuries			5.3

Table D.3.3-7. Program-Wide Risks Associated with the Routine Management of HW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Hazardous Chemicals		Physical Hazards
		Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem) Cancer Fatalities Cancer Incidence Genetic Effects	2.5E-2		
Noninvolved Worker MEI	Dose (rem) Cancer Fatalities Cancer Incidence Genetic Effects Hazard Index	1.1E-5	1.5E-1	
Offsite Population	Dose (person-rem) Cancer Fatalities Cancer Incidence Genetic Effects	6.0E-2		
Offsite MEI	Dose (rem) Cancer Fatalities Cancer Incidence Genetic Effects Hazard Index	2.4E-6	3.2E-2	
WM Workers	Dose (FTE-rem) Cancer Fatalities Cancer Incidence Genetic Effects Exposure Index Construction Fatalities Construction Injuries Operation Fatalities Operation Injuries	1.2	6.1	2.6E-2 1.2E1 4.3E-2 3.7E1

Table D.3.3–8. Program-Wide Risks Associated with the Routine Management of HW Under the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Hazardous Chemicals		Physical Hazards
		Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem) Cancer Fatalities Cancer Incidence Genetic Effects	3.3E-2		
Noninvolved Worker MEI	Dose (rem) Cancer Fatalities Cancer Incidence Genetic Effects Hazard Index	3.1E-5	4.1E-1	
Offsite Population	Dose (person-rem) Cancer Fatalities Cancer Incidence Genetic Effects	9.6E-2		
Offsite MEI	Dose (rem) Cancer Fatalities Cancer Incidence Genetic Effects Hazard Index	5.0E-6	6.6E-2	
WM Workers	Dose (FTE-rem) Cancer Fatalities Cancer Incidence Genetic Effects Exposure Index Construction Fatalities Construction Injuries Operation Fatalities Operation Injuries	1.8	6.2	2.8E-2 1.2E1 4.5E-2 3.8E1

Table D.3.3–9. Risks Associated with the Routine Management of HW Under the No Action Alternative, By Installation

Installation	Population[a]	Fatalities[b]	Cancer Incidence				
		Workers	Offsite Population	Offsite MEI[c]	Noninvolved Worker Population	Noninvolved Worker MEI[c]	Workers
INEL	153061 / 16	2.6E-3	3.4E-5	4.6E-9	4.4E-5	3.7E-8	1.8E-2
ORR	881652 / 36	5.6E-3	7.4E-3	3.9E-7	2.5E-3	2.4E-6	7.6E-2
TOTAL		8.2E-3	7.5E-3	3.9E-7	2.5E-3	2.4E-6	9.4E-2

[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.
[c] MEI—Most-exposed individual.

Table D.3.3–10. Risks Associated with the Routine Management of HW Under the Regionalized Alternative 1, By Installation

Installation	Population[a]	Fatalities[b]	Cancer Incidence				
		Workers	Offsite Population	Offsite MEI[c]	Noninvolved Worker Population	Noninvolved Worker MEI[c]	Workers
Hanford	377645 / 91	1.8E-2	4.3E-3	1.4E-7	2.6E-3	5.0E-6	2.9E-1
INEL	153061 / 35	6.8E-3	1.0E-4	1.4E-8	1.4E-4	1.1E-7	7.6E-2
LANL	159152 / 88	1.7E-2	1.9E-2	2.4E-6	9.5E-3	5.9E-6	3.0E-1
ORR	881652 / 101	2.0E-2	3.6E-2	1.8E-6	1.1E-2	1.1E-5	4.2E-1
SRS	620618 / 40	7.9E-3	1.2E-3	1.5E-8	5.9E-4	6.7E-7	9.3E-2
TOTAL		6.9E-2	6.0E-2	2.4E-6	2.5E-2	1.1E-5	1.2

[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.
[c] MEI—Most-exposed individual.

Table D.3.3–11. Risks Associated with the Routine Management of HW Under the Regionalized Alternative 2, By Installation

Installation	Population[a]	Fatalities[b]	Cancer Incidence				
		Workers	Offsite Population	Offsite MEI[c]	Noninvolved Worker Population	Noninvolved Worker MEI[c]	Workers
INEL	153061 / 160	3.1E-2	9.7E-4	1.3E-7	1.3E-3	1.1E-6	7.4E-1
ORR	881652 / 212	4.1E-2	9.5E-2	5.0E-6	3.2E-2	3.1E-5	1.1
TOTAL		7.3E-2	9.6E-2	5.0E-6	3.3E-2	3.1E-5	1.8

[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.
[c] MEI—Most-exposed individual.

Table D.3.3–12. Constituents in HW Contributing the Highest Risk of Cancer Incidence to the Offsite Population at Each Installation, By Alternative

Alternative	Installation				
	Hanford	INEL	LANL	ORR	SRS
No Action	—	chromium (VI)[a] 2.7E-5[b]	—	chromium (VI) 5.9E-3	—
Regionalized 1	chromium (VI) 3.5E-3	chromium (VI) 8.3E-5	chromium (VI) 1.5E-2	chromium (VI) 2.9E-2	chromium (VI) 9.4E-4
Regionalized 2	—	chromium (VI) 7.8E-4	—	chromium (VI) 7.7E-2	—

[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 program-wide impacts to each receptor population and a discussion of the overall results of the HW human health risk analysis.

D.3.3.4.1 *Program-Wide Trends in Human Health Risks Associated with HW Management Alternatives*

Offsite Population. For the offsite population, the program-wide risk of cancer incidence associated with routine treatment of HW is lowest for No Action (7.5E-3 cancer incidences distributed over a total affected population of approximately 1 million), and slightly higher for Regionalized 1 and 2 (6.0E-2 over a total population of approximately 2 million and 9.6E-2 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 installations).

Noninvolved Worker Population. The program-wide 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-2 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.

Most-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-5 to E-6 range. Following EPA guidance developed for evaluating cancer incidence (see Section D.2.14), the risks to the MEIs in Regionalized 1 and 2 are within target exposure levels. Most of the risk in these alternatives is attributable to the presence of the inhalation carcinogen chromium (VI) in the source term (ANL, 1995d).

The hazard indices for both MEIs (indicating the worst-case 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. Program-wide 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-2 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 installations, while the worst-case 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 installations treat 80% to 90% of the DOE inventory of commercially treatable HW. The difference in risks at these installations 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 installations across all alternatives (see Table D.3.3-12). Cancer incidence risks to the offsite MEI are in the E-6 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 installation-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 installations in all alternatives (ORNL, 1995e).

The cancer incidence risk to the noninvolved worker MEI is between 1E-6 and 1E-4 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 installation cancer incidence risks are always at ORR for workers, although differences between installations 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 installations 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 installations 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 installations and treating 80% to 90% at two installations result in nearly the same overall health risks to all populations. Within each alternative, the highest-risk installations for exposure are also the highest-risk installations 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 installation and each alternative. Thsee 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 worst-case accidents (i.e., those for which the attendant risks are highest) at each installation for each alternative are reported in Table D.3.3-15. These results are:

- The estimated cancer incidence in the installation'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 most-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 an installation).

The risks to noninvolved workers from single-drum accidents are not reported in this appendix; those results can be found in ORNL (1995e).

Note that the single-drum accident that poses the highest risks to the offsite population may not be the same as the worst-case accident for workers (because exposure scenarios and pathways often differ between workers and the other receptors).

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.3.3.5.2 *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.

D.3.3.5.3 *Treatment Facility Accidents*

The treatment facility accidents analyzed for HW include (1) an incinerator explosion and resulting feedstock fire; (2) an earthquake followed by an incinerator facility fire; and (3) a large or small aircraft impact (assuming the same scenarios as for the storage facility accidents) and resulting incinerator facility 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 facility-wide 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) (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.

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" (1E-4 to 1E-2) to "very unlikely"(1E-6 to 1E-4). The incinerator explosion and fire is considered to be "anticipated" (greater than 1E-2); the earthquake causing a storage facility spill or an incinerator fire is considered "unlikely" to "very unlikely," depending on the location of the installation; and aircraft impact is regarded as "extremely unlikely" (less than 1E-6), depending on installation 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 worst-case single-drum, single-contaminant releases, by installation 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 installation and alternative. Table D.3.3-20 provides the sizes of the offsite, noninvolved worker, and worker populations at each installation.

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 Installation

Installation	Alternative	Receptor and Endpoint							
		Offsite Population		Offsite MEI[b]		Worker Population		Most-Exposed Worker	
		Accident[c]	CI[d]	Accident	HI[e]	Accident	CI	Accident	IDLH Index
Hanford	Reg. 1[a]	5E (U)[f]	3.2E-4	2D (U)	8.1E-2	5E (U)	2.5E-3	5F (VU)	6.4E1
INEL	Reg. 1	5E (U)	2.1E-4	2D (U)	5.3E-1	5E (U)	2.5E-3	5F (U)	6.4E1
LANL	Reg. 1	5E (U)	3.0E-4	2D (U)	9.9E-1	5E (U)	2.5E-3	5F (U)	6.4E1
ORR	Reg. 1	5E (VU)	5.9E-3	2D (U)	5.8	5E (VU)	2.5E-3	5F (VU)	6.4E1
SRS	Reg. 1	5E (U)	2.6E-5	2D (U)	8.1E-2	5E (U)	2.5E-3	5F (0)[g]	6.4E1
INEL	Reg. 2[a]	5E (U)	2.1E-4	2D (U)	5.3E-1	5E (U)	2.5E-3	5F (U)	6.4E1
ORR	Reg. 2	5E (U)	5.9E-3	2D (U)	5.8	5E (U)	2.5E-3	5F (U)	6.4E1

[a] Reg.1—Regionalized Alternative 1; Reg. 2—Regionalized Alternative 2.
[b] MEI—most-exposed individual.
[c] Worst-case single-drum accident type.
[d] CI—risk of cancer incidence associated with exposure to chemical carcinogens.
[e] HI—hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[f] 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-6).
[g] The annual frequency of this accident occurring at SRS is 0.

Table D.3.3-16. Risks Associated with Potential Facility-Wide HW Storage Accidents Under the Regionalized Alternative 1, By Accident and Installation

Installation	Offsite Pop CI[a]	Offsite MEI[b] HI[c]	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Storage Facility Fire						
Hanford (U)[d]	2.8E-3	1.1	1.5E-5	5.6	1.8E-2	9.0E2
INEL (U)	1.7E-3	1.5	6.8E-3	1.4E1	2.0E-2	5.1E2
LANL (U)	8.3E-3	3.1E1	1.8E-3	4.4E2	6.6E-2	2.4E3
ORR (U)	1.8E-2	7.6E1	2.3E-2	8.4E2	5.3E-3	6.0E2
SRS (U)	5.6E-4	1.7	2.8E-3	1.1E2	5.4E-2	1.3E3
Large or Small Aircraft Impact and Storage Facility Fire						
Hanford (EU) (large)	2.8E-3	1.2	1.4E-5	6.2	1.8E-2	1.4E3
INEL (EU) (large)	1.7E-3	1.6	6.9E-3	1.4E1	2.0E-2	5.3E2
LANL (EU) (small)	8.3E-3	3.2E1	1.8E-3	4.5E2	6.6E-2	2.7E3
ORR (EU) (small)	1.8E-2	7.7E1	2.3E-2	8.5E2	5.3E-3	6.8E2
SRS (EU) (large)	5.9E-4	1.7	2.8E-3	1.1E2	5.4E-2	1.3E3
Earthquake and Resulting Spill of Multiple Storage Containers						
Hanford (VU)	0.0[e]	1.6E-3	0.0[e]	8.5E-3	0.0[e]	1.2
LANL (U)	0.0[e]	2.0E-2	0.0[e]	2.8E-1	0.0[e]	1.2

[a] CI—risk of cancer incidence associated with exposure to chemical carcinogens.
[b] MEI—most-exposed individual.
[c] HI—hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[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-6).
[e] Zero indicates that no carcinogen is released in accident scenario.

Table D.3.3–17. Risks Associated with Potential Facility-Wide HW Storage Accidents Under the Regionalized Alternative 2, By Accident and Installation

Installation	Offsite Pop CI[a]	Offsite MEI[b] HI[c]	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Storage Facility Fire						
INEL (U)[d]	1.2E-2	3.6E1	4.8E-2	3.2E2	1.4E-1	5.1E3
ORR (U)	1.6E-1	2.4E2	2.1E-1	2.6E3	6.1E-2	2.2E3
Large or Small Aircraft Impact and Storage Facility Fire						
INEL (EU) (large)	1.2E-2	3.7E1	4.8E-2	3.3E2	1.4E-1	6.2E3
ORR (EU) (small)	1.6E-1	2.4E2	2.1E-1	2.6E3	6.1E-2	2.3E3
Earthquake and Resulting Spill of Multiple Storage Containers						
INEL (U)	0.0[e]	1.9E-1	0.0[e]	1.7	0.0[e]	8.0
ORR (U)	0.0[e]	1.1E-1	0.0[e]	1.3	0.0[e]	1.2

[a] CI—risk of cancer incidence associated with exposure to chemical carcinogens.
[b] MEI—most-exposed individual.
[c] HI—hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[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-6).
[e] Zero indicates that no carcinogen is released in accident scenario.

Table D.3.3-18. Risks Associated with Potential Facility-Wide HW Treatment Accidents Under the Regionalized Alternative 1, By Accident and Installation

Installation		Offsite Pop CI[a]	Offsite MEI[b] HI[c]	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Incinerator Explosion and Fire							
Hanford	(A)[d]	1.9E-5	8.0E-2	9.8E-8	4.3E-1	1.0E-6	3.9E1
INEL	(A)	2.0E-4	0.0[e]	4.7E-4	0.0[e]	2.5E-4	7.9E1
LANL	(A)	3.1E-4	9.5E-1	6.1E-5	7.3	7.5E-4	1.2E2
ORR	(A)	5.5E-3	3.5	4.8E-4	3.7	1.0E-3	2.0E2
SRS	(A)	7.6E-7	8.0E-2	3.4E-6	4.4	5.0E-7	3.9E1
Large or Small Aircraft Impact and Incinerator Facility Fire							
Hanford (large)	(EU)	5.6E-5	1.8E-1	2.9E-7	9.8E-1	3.0E-6	3.6E2
INEL (large)	(EU)	4.1E-4	8.3E-2	9.4E-4	4.6E-1	5.0E-4	2.3E2
LANL (small)	(EU)	3.4E-4	1.3	6.6E-5	9.9	7.6E-4	4.8E2
ORR (small)	(EU)	1.1E-2	6.8	9.7E-4	7.1	2.0E-3	3.2E2
SRS (large)	(EU)	2.9E-5	8.1E-2	1.3E-4	4.4	5.0E-4	1.2E2
Earthquake and Incinerator Facility Fire							
Hanford	(VU)	3.7E-5	1.0E-1	2.0E-7	5.5E-1	2.0E-6	3.2E2
INEL	(VU)	2.1E-4	8.3E-2	4.8E-4	4.6E-1	2.5E-4	1.6E2
LANL	(VU)	3.5E-4	1.0	6.8E-5	7.8	7.8E-4	2.0E2
ORR	(VU)	1.1E-2	6.8	9.7E-4	7.1	2.0E-3	3.2E2
SRS	(VU)	2.7E-5	8.1E-2	1.2E-4	4.4	5.0E-4	1.2E2

[a] CI—risk of cancer incidence associated with exposure to chemical carcinogens.
[b] MEI—most-exposed individual.
[c] HI—hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[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-6).
[e] Zero indicates that no acute RfD was available for contaminant; cancer incidence only was calculated.

Table D.3.3-19. Risks Associated with Potential Facility-Wide HW Treatment Accidents Under the Regionalized Alternative 2, By Accident and Installation

Installation	Offsite Pop CI[a]	Offsite MEI[b] HI[c]	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Incinerator Explosion and Fire						
INEL (A)[d]	2.3E-4	4.9E-1	5.2E-4	2.7	1.3E-3	2.0E2
ORR (A)	6.0E-3	6.6	5.2E-4	6.9	1.3E-3	1.6E2
Large or Small Aircraft Impact and Incinerator Facility Fire						
INEL (large) (EU)	4.5E-4	1.5	1.0E-3	8.5	2.5E-3	6.4E2
ORR (small) (EU)	1.2E-2	1.1E1	1.0E-3	1.1E1	2.5E-3	5.6E2
Earthquake and Incinerator Facility Fire						
INEL (VU)	8.6E-4	2.1	2.0E-3	1.2E1	5.0E-3	9.9E2
ORR (VU)	1.2E-2	1.1E1	1.0E-3	1.1E1	2.5E-3	5.6E2

[a] CI—risk of cancer incidence associated with exposure to chemical carcinogens.
[b] MEI—most-exposed individual.
[c] HI—hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[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-6).

Table D.3.3-20. Size of Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Potential HW Treatment and Storage Accidents, by Installation

Installation	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 an installation, 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 installations, while treatment of 50% of DOE HW is distributed across five installations 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 installations by roughly 1 order of magnitude for storage accidents and by only a slight margin for treatment accidents.

The worst-case single-drum storage accidents for the offsite population and MEI involve releases of cadmium and mercury vapor. The worst-case single-drum accidents for 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" (1E-4 to 1E-2) whereas the aircraft impact scenario is designated "extremely unlikely" (less than 1E-6). For treatment facility accidents, consequences are generally similar among accident types at a given installation; however, the incinerator explosion is considered much more likely (greater than 1E-2 or "anticipated") than other scenarios. The most common controlling contaminants in HW accident scenarios are cadmium and mercury vapor. The highest-risk installations 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 installation, 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-5 to 5.9E-3 in Regionalized 1 and from 2.1E-4 to 5.9E-3 in Regionalized 2. The highest cancer incidence is at ORR in both Regionalized 1 and 2 (5.9E-3 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-4, 3.0E-4, and 2.1E-4, respectively). The lowest cancer incidence risks are at SRS in Regionalized 1 (2.6E-5). The consequences at an installation of the worst-case 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" (1E-6 to 1E-4) to "unlikely" (1E-4 to 1E-2) in Regionalized 2. The accident is considered "unlikely" at all other installations 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 an installation (see Tables D.3.3-16 and D.3.3-17). However, facility fires are projected to occur more frequently than airplane crashes ("unlikely" [1E-4 to 1E-2] versus "extremely unlikely" [less than 1E-6], respectively). In general, the risks at each installation 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 installations in Regionalized 2 while treatment of 50% of DOE HW is distributed across five installations 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-2 and 1.6E-1, respectively, in an affected population of 881,652), INEL in Regionalized 2 (1.2E-2 in a population of 153,061), and LANL in Regionalized 1 (8.3E-3 in a population of 159,152). At all three installations, the controlling contaminant is cadmium. In earthquake scenarios, no carcinogens are assumed to be released (source terms contain noncarcinogens only).

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-7 to 1.1E-2 in Regionalized 1 and from 2.3E-4 to 1.2E-2 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 installation, 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-7) 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-2); the aircraft impact scenario is "extremely unlikely" (less than 1E-6); and the earthquake scenario is "very unlikely" (1E-6 to 1E-4).

ORR is the highest-risk installation 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-2 in Regionalized 1 and 1.2E-2 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 risks to noninvolved workers from single-drum accidents are not presented in this appendix, but can be found in a separate ORNL technical report (1995e).

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 installation, 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 installation. 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-5 to 2.3E-2 in Regionalized 1 and from 4.8E-2 to 2.1E-1 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-2 and 2.1E-1, 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-3 in Regionalized 1 and 4.8E-2 in Regionalized 2). Cadmium is the controlling contaminant at both installations. The installation with the lowest cancer incidence risks to noninvolved workers from storage accidents is Hanford in Regionalized 1.

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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-8 to 9.7E-4 in Regionalized 1 and from 5.2E-4 to 2.0E-3 in Regionalized 2. In both alternatives, cancer incidence risks to noninvolved workers are similar among accident types at a given installation, 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-6) 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 installation 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-4 to 9.4E-4 in Regionalized 1 and from 5.2E-4 to 2.0E-3 in Regionalized 2. ORR cancer incidence risks are very similar to those at INEL, ranging from 4.8E-4 to 9.7E-4 in Regionalized 1 and from 5.2E-4 to 1.0E-3 in Regionalized 2. The controlling contaminant is cadmium at both installations.

D.3.3.8.5 *Risks to the Most-Exposed Offsite Individual from Single-Drum Accidents*

The worst-case 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-1 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 installations and alternatives.

D.3.3.8.6 *Risks to the Most-Exposed Noninvolved Worker and Most-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

7.7E1 and 2.4E2, respectively); INEL in Regionalized 2 (approximately 3.7E1); and LANL in Regionalized 1 (approximately 3.2E1). The same trend holds true for the noninvolved worker MEI. At all three installations 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 installation. 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 1.1E1); 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 installations 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 1.1E1); 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-3) is 5E, the forklift accident leading to a spill and fire with release of cadmium fumes (see Table D.3.3-13). (This scenario was also the worst-case single-drum accident involving a carcinogen for the offsite population.) The worst-case single-drum accident for workers 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 6.4E1, 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 installation, the consequences of the worst-case 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 installation (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-1 for each accident). The highest IDLH indices are also for the storage facility fire and aircraft crash at INEL in Regionalized 2 (5.1E3 and 6.2E3, 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 installation. 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-7; 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 installation risks are for all accident types at ORR in both

alternatives (ranging from 1.0E-3 to 2.0E-3) and INEL in Regionalized 2 (ranging from 1.3E-3 to 5.0E-3). The controlling contaminant is cadmium at both installations.

IDLH indices are similar among accident types at a given installation 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). 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/gm [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. Following are the DOE installations that generate or store TRUW (note that the abbreviations given here are used throughout this appendix):

- 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 Laboratory-California (SNL-CA), Livermore, California
- Savannah River Site (SRS), Aiken, South Carolina
- University of Missouri at Columbia (U of Mo), Columbia, Missouri
- West Valley Demonstration Project (WVDP), West Valley, New York

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 installation 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 installations 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.

Chapters 3 and 8 of the PEIS and the TRUW technical report (ANL, 1995b) provide more detailed information on this waste, including TRUW inventories at DOE installations, 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 CH-TRUW retrieval, packaging, certification, and indefinite interim storage at all generator installations. 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 Decentralized Alternative presents the risks of treating wastes to WIPP waste acceptance criteria and storing them at 10 installations.
- In Regionalized Alternative 1, CH-TRUW is consolidated, treated to minimize gas generation, and stored at five installations.
- In Regionalized Alternatives 2 and 3, CH-TRUW is consolidated, treated to meet RCRA LDRs, and stored at five and three installations, respectively.
- In the Centralized Alternative, CH-TRUW is consolidated, treated to meet RCRA LDRs, and stored at one installation.

In Regionalized 1 and 2, consolidation, treatment, and storage take place at the same five installations. 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 installation(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 installations ship their wastes to regionalized or centralized consolidation installations for treatment and storage. 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, U of Mo, and the WVDP so risks at these installations were not evaluated (ANL, 1995b).

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	U of Mo[e]	WVDP[f]	WIPP
No Action Alternative	T[g]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	
No treatment/store at 16	S[h]	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

[a,e,f] Data for ETEC, U of Mo, and WVDP were not available so risks at these installations were not evaluated.
[b] Includes CH-TRUW from ANL-W.
[c] Includes CH-TRUW from SNL-CA.
[d] Includes CH-TRUW from ITRI.
[g] T—treatment installation.
[h] S—storage installation.

Table D.3.4–2. PEIS Consolidation and Treatment Strategies for CH-TRUW

Alternative	Origin	Treatment and Storage Destination
No Action Alternative No treatment; store at 16 installations	All installations	Generators store own waste
Decentralized Alternative Treat to WIPP-WAC and store at 10 installations	ANL-E Hanford, LBL INEL/ANL-W[a] LANL, SNL-NM/ITRI[b] LLNL/SNL-CA[c] Mound, WVDP[d] NTS, ETEC[e] ORR, PGDP, U of Mo[f] RFETS SRS	ANL-E Hanford INEL LANL LLNL Mound NTS ORR RFETS SRS
Regionalized Alternative 1 Treat to minimize gas generation and store at 5 installations	Hanford, LBL, LLNL/SNL-CA INEL/ANL-W, ETEC, NTS LANL, SNL-NM/ITRI RFETS SRS, ANL-E, Mound, ORR, PGDP, U of Mo, WVDP	Hanford INEL LANL RFETS SRS
Regionalized Alternative 2 Treat to RCRA LDRs and store at 5 installations	Hanford, LBL, LLNL/SNL-CA INEL/ANL-W, ETEC, NTS LANL, SNL-NM/ITRI RFETS SRS, ANL-E, Mound, ORR, PGDP, U of Mo, WVDP	Hanford INEL LANL RFETS SRS
Regionalized Alternative 3 Treat to RCRA LDRs and store at 3 installations	Hanford, LBL, LLNL/SNL-CA INEL/ANL-W, ETEC, LANL, NTS, RFETS, SNL-NM/ITRI SRS, ANL-E, Mound, ORR, PGDP, U of Mo, WVDP	Hanford INEL SRS
Centralized Alternative Treat to RCRA LDRs and store at WIPP	All installations	WIPP

[a,b,c] 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.
[d,e,f] Source terms for WVDP, ETEC, and U of Mo were not available so risks at these installations were not evaluated.

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 design and construction of new facilities will begin in 1995, and 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, 1995b). 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 7080 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 worst-case exposure of the noninvolved worker MEI and offsite MEI to noncarcinogenic, hazardous chemicals. The EI indicates the analogous worst-case 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 low-level and low-level mixed waste. For more information on the treatment modules, see ORNL (1994b).

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*, program-wide 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 program-wide 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 installation and alternative.

Table D.3.4–3. Summary of Program-Wide Risks Associated with Routine Management of CH-TRUW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF[a]	CI[b]	CF	CI	CF	CI	C&OF[c]
No Action Alternative	2.3E-5	7.8E-5	2.1E-6	7.1E-6	9.6E-3	3.4E-2	3.5E-1
Decentralized Alternative	1.2E-4	4.2E-4	1.1E-5	3.9E-5	6.0E-1	2.1	2.1
Regionalized Alternative 1	1.7E-4	5.9E-4	1.6E-5	5.5E-5	6.3E-1	2.2	2.7
Regionalized Alternative 2	3.3	11.3	3.4E-1	1.2	6.1E-1	2.1	4.4
Regionalized Alternative 3	2.6	8.9	2.9E-1	9.9E-1	6.6E-1	2.3	3.6
Centralized Alternative	6.1E-1	2.1	5.0E-2	1.7E-1	6.8E-1	2.4	3.1

[a] CF—cancer fatality associated with radionuclide exposure.
[b] CI—cancer incidence associated with exposure to radionuclides and carcinogenic chemicals.
[c] 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	19,333,201	70,681	1,690
Decentralized	24,373,318	92,462	6,473
Regionalized 1	23,491,666	88,653	8,439
Regionalized 2	23,491,666	88,653	14,569
Regionalized 3	23,491,666	88,653	11,991
Centralized	24,473,207	89,713	10,237

Table D.3.4-5. Summary of Program-Wide Risks Associated with Routine Management of CH-TRUW: Risks To the Offsite and Noninvolved Worker Most-Exposed Individuals, by Alternative

Alternative	Offsite MEI				Noninvolved Worker MEI			
	CF[a]	Rad CI[b]	Chem CI[c]	HI[d]	CF	Rad CI	Chem CI	HI
No Action	4.4E-10	1.5E-9	3.1E-13	2.6E-11	1.3E-9	4.4E-9	9.9E-13	2.7E-10
Decentralized	5.7E-9	1.9E-8	2.8E-12	1.5E-10	4.8E-9	1.6E-8	8.9E-12	1.4E-9
Regionalized 1	6.9E-9	2.3E-8	4.8E-12	2.2E-10	7.7E-9	2.6E-8	1.5E-11	2.5E-9
Regionalized 2	6.7E-5	2.3E-4	4.8E-12	1.1E-8	2.4E-4	8.2E-4	1.5E-11	1.3E-7
Regionalized 3	2.4E-5	8.2E-5	4.8E-12	3.0E-9	2.4E-4	8.2E-4	1.5E-11	1.3E-7
Centralized	1.6E-4	5.4E-4	4.8E-12	7.6E-8	1.9E-4	6.5E-4	1.5E-11	4.6E-7

[a] CF—cancer fatality associated with exposure to radionuclides.
[b] Rad CI—cancer incidence associated with exposure to radionuclides.
[c] Chem CI—cancer incidence associated with exposure to carcinogenic chemicals.
[d] HI—hazard index associated with exposure to noncarcinogenic, toxic chemicals.

Table D.3.4-6. Program-Wide 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)	4.2E-3			
	Cancer Fatalities	2.1E-6			
	Cancer Incidence	7.1E-6	3.5E-9		
	Genetic Effects	4.2E-7			
Noninvolved Worker MEI	Dose (rem)	2.6E-6			
	Cancer Fatalities	1.3E-9			
	Cancer Incidence	4.4E-9	9.9E-13		
	Genetic Effects	2.6E-10			
	Hazard Index			2.7E-10	
Offsite Population	Dose (person-rem)	4.6E-2			
	Cancer Fatalities	2.3E-5			
	Cancer Incidence	7.8E-5	1.4E-8		
	Genetic Effects	4.6E-6			
Offsite MEI	Dose (rem)	8.7E-7			
	Cancer Fatalities	4.4E-10			
	Cancer Incidence	1.5E-9	3.1E-13		
	Genetic Effects	8.7E-11			
	Hazard Index			2.6E-11	
WM Workers	Dose (FTE-rem)	2.4E1			
	Cancer Fatalities	9.6E-3			
	Cancer Incidence	3.4E-2	3.8E-7		
	Genetic Effects	1.4E-3			
	Exposure Index			2.6E-6	
	Construction Fatalities				1.4E-1
	Construction Injuries				6.2E1
	Operation Fatalities				2.0E-1
	Operation Injuries				1.7E2

Table D.3.4–7. Program-Wide 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)	2.3E-2			
	Cancer Fatalities	1.1E-5			
	Cancer Incidence	3.9E-5	3.4E-8		
	Genetic Effects	2.3E-6			
Noninvolved Worker MEI	Dose (rem)	9.5E-6			
	Cancer Fatalities	4.8E-9			
	Cancer Incidence	1.6E-8	8.9E-12		
	Genetic Effects	9.5E-10			
	Hazard Index			1.4E-9	
Offsite Population	Dose (person-rem)	2.4E-1			
	Cancer Fatalities	1.2E-4			
	Cancer Incidence	4.2E-4	1.3E-7		
	Genetic Effects	2.4E-5			
Offsite MEI	Dose (rem)	1.1E-5			
	Cancer Fatalities	5.7E-9			
	Cancer Incidence	1.9E-8	2.8E-12		
	Genetic Effects	1.1E-9			
	Hazard Index			1.5E-10	
WM Workers	Dose (FTE-rem)	1.5E3			
	Cancer Fatalities	6.0E-1			
	Cancer Incidence	2.1	1.0E-5		
	Genetic Effects	9.0E-2			
	Exposure Index			3.1E-5	
	Construction Fatalities				1.4
	Construction Injuries				5.9E2
	Operation Fatalities				7.8E-1
	Operation Injuries				6.7E2

Table D.3.4–8. Program-Wide Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 1

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	3.2E-2			
	Cancer Fatalities	1.6E-5			
	Cancer Incidence	5.5E-5	5.8E-8		
	Genetic Effects	3.2E-6			
Noninvolved Worker MEI	Dose (rem)	1.5E-5			
	Cancer Fatalities	7.7E-9			
	Cancer Incidence	2.6E-8	1.5E-11		
	Genetic Effects	1.5E-9			
	Hazard Index			2.5E-9	
Offsite Population	Dose (person-rem)	3.4E-1			
	Cancer Fatalities	1.7E-4			
	Cancer Incidence	5.9E-4	2.3E-7		
	Genetic Effects	3.4E-5			
Offsite MEI	Dose (rem)	1.4E-5			
	Cancer Fatalities	6.9E-9			
	Cancer Incidence	2.3E-8	4.8E-12		
	Genetic Effects	1.4E-9			
	Hazard Index			2.2E-10	
WM Workers	Dose (FTE-rem)	1.6E3			
	Cancer Fatalities	6.3E-1			
	Cancer Incidence	2.2	2.0E-5		
	Genetic Effects	9.4E-2			
	Exposure Index			3.1E-5	
	Construction Fatalities				1.7
	Construction Injuries				7.5E2
	Operation Fatalities				1.0
	Operation Injuries				8.7E2

Table D.3.4–9. Program-Wide Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 2

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	6.9E2			
	Cancer Fatalities	3.4E-1			
	Cancer Incidence	1.2	5.6E-8		
	Genetic Effects	6.9E-2			
Noninvolved Worker MEI	Dose (rem)	4.9E-1			
	Cancer Fatalities	2.4E-4			
	Cancer Incidence	8.2E-4	1.5E-11		
	Genetic Effects	4.9E-5			
	Hazard Index			1.3E-7	
Offsite Population	Dose (person-rem)	6.7E3			
	Cancer Fatalities	3.3			
	Cancer Incidence	1.1E1	2.2E-7		
	Genetic Effects	6.7E-1			
Offsite MEI	Dose (rem)	1.3E-1			
	Cancer Fatalities	6.7E-5			
	Cancer Incidence	2.3E-4	4.8E-12		
	Genetic Effects	1.3E-5			
	Hazard Index			1.1E-8	
WM Workers	Dose (FTE-rem)	1.5E3			
	Cancer Fatalities	6.1E-1			
	Cancer Incidence	2.1	2.5E-5		
	Genetic Effects	9.2E-2			
	Exposure Index			8.6E-4	
	Construction Fatalities				2.6
	Construction Injuries				1.1E3
	Operation Fatalities				1.8
	Operation Injuries				1.5E3

Table D.3.4-10. Program-Wide Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 3

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	5.8E2			
	Cancer Fatalities	2.9E-1			
	Cancer Incidence	9.9E-1	5.7E-8		
	Genetic Effects	5.8E-2			
Noninvolved Worker MEI	Dose (rem)	4.9E-1			
	Cancer Fatalities	2.4E-4			
	Cancer Incidence	8.2E-4	1.5E-11		
	Genetic Effects	4.9E-5			
	Hazard Index			1.3E-7	
Offsite Population	Dose (person-rem)	5.2E3			
	Cancer Fatalities	2.6			
	Cancer Incidence	8.9	2.2E-7		
	Genetic Effects	5.2E-1			
Offsite MEI	Dose (rem)	4.8E-2			
	Cancer Fatalities	2.4E-5			
	Cancer Incidence	8.2E-5	4.8E-12		
	Genetic Effects	4.8E-6			
	Hazard Index			3.0E-9	
WM Workers	Dose (FTE-rem)	1.6E3			
	Cancer Fatalities	6.6E-1			
	Cancer Incidence	2.3	3.6E-5		
	Genetic Effects	9.8E-2			
	Exposure Index			8.6E-4	
	Construction Fatalities				2.2
	Construction Injuries				9.4E2
	Operation Fatalities				1.5
	Operation Injuries				1.2E3

Table D.3.4-11. Program-Wide 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)	9.9E1			
	Cancer Fatalities	5.0E-2			
	Cancer Incidence	1.7E-1	6.6E-8		
	Genetic Effects	9.9E-3			
Noninvolved Worker MEI	Dose (rem)	3.8E-1			
	Cancer Fatalities	1.9E-4			
	Cancer Incidence	6.5E-4	1.5E-11		
	Genetic Effects	3.8E-5			
	Hazard Index			4.6E-7	
Offsite Population	Dose (person-rem)	1.2E3			
	Cancer Fatalities	6.1E-1			
	Cancer Incidence	2.1	2.3E-7		
	Genetic Effects	1.2E-1			
Offsite MEI	Dose (rem)	3.2E-1			
	Cancer Fatalities	1.6E-4			
	Cancer Incidence	5.4E-4	4.8E-12		
	Genetic Effects	3.2E-5			
	Hazard Index			7.6E-8	
WM Workers	Dose (FTE-rem)	1.7E3			
	Cancer Fatalities	6.8E-1			
	Cancer Incidence	2.4	8.6E-5		
	Genetic Effects	1.0E-1			
	Exposure Index			1.1E-3	
	Construction Fatalities				1.8
	Construction Injuries				7.9E2
	Operation Fatalities				1.2
	Operation Injuries				1.1E3

Table D.3.4–12. Risks Associated with Managing CH-TRUW Under the No Action Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 404	3.5E-7	7.2E-12	8.9E-2	1.2E-6	2.5E-11	2.5E-2
INEL	153061 / 55	2.6E-9	3.3E-13	1.1E-2	8.9E-9	1.1E-12	3.8E-6
LBL	5856829 / 0	4.8E-10	7.0E-15	3.4E-5	1.7E-9	2.5E-14	3.2E-12
LLNL	6324234 / 148	1.1E-6	1.8E-11	3.0E-2	3.8E-6	6.1E-11	2.5E-5
LANL	159152 / 257	4.1E-6	4.4E-10	5.3E-2	1.4E-5	1.5E-9	1.2E-3
PGDP	500502 / 0	0.00	0.00	0.00	0.00	0.00	0.00
Mound	3032983 / 0	0.00	0.00	0.00	0.00	0.00	0.00
NTS	14266 / 0	0.00	0.00	0.00	0.00	0.00	0.00
RFETS	2171877 / 353	3.0E-6	4.1E-11	7.3E-2	1.0E-5	1.4E-10	2.9E-4
SNL-NM	610714 / 0	0.00	0.00	0.00	0.00	0.00	0.00
SRS	620618 / 367	1.4E-5	1.3E-10	7.6E-2	4.7E-5	4.4E-10	7.4E-3
ANL-E	7939785 / 106	5.5E-7	3.1E-12	2.2E-2	1.9E-6	1.0E-11	3.3E-6
TOTAL		2.3E-5	4.4E-10	3.6E-1	7.8E-5	1.5E-9	3.4E-2

[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 ("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.
[d] Offsite.

Table D.3.4–13. Risks Associated with Managing CH-TRUW Under the Decentralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 275	1.8E-6	9.9E-12	1.0E-1	6.1E-6	3.4E-11	3.0E-2
INEL	153061 / 2303	1.1E-6	1.4E-10	1.0	3.8E-6	4.8E-10	8.7E-1
LBL	5856829 / 1	6.3E-9	9.4E-14	8.4E-3	2.1E-8	3.2E-13	7.6E-9
LLNL	6324234 / 354	3.5E-6	5.7E-11	1.1E-1	1.2E-5	2.0E-10	2.0E-3
LANL	159152 / 1064	5.4E-5	5.7E-9	4.9E-1	1.8E-4	1.9E-8	5.0E-1
ORR	881652 / 2	0.00	0.00	4.7E-4	0.00	0.00	7.9E-14
Mound	3032983 / 84	8.4E-7	4.8E-11	3.2E-2	2.9E-6	1.6E-10	4.8E-4
NTS	14266 / 204	1.1E-10	3.0E-14	6.8E-2	3.9E-10	1.0E-13	7.3E-4
PGDP	500502 / 15	3.5E-9	3.9E-13	1.3E-2	1.2E-8	1.3E-12	1.6E-6
RFETS	2171877 / 664	9.3E-6	1.3E-10	2.2E-1	3.2E-5	4.3E-10	2.7E-2
SNL-NM	610714 / 2	2.7E-9	1.1E-13	8.7E-3	9.1E-9	3.6E-13	2.1E-8
SRS	620618 / 790	5.1E-5	4.8E-10	3.5E-1	1.7E-4	1.6E-9	3.1E-1
Hanford	377645 / 715	1.4E-6	2.9E-11	3.3E-1	4.8E-6	9.9E-11	3.6E-1
TOTAL		1.2E-4	5.7E-9	2.7	4.2E-4	1.9E-8	2.1

[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 ("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.
[d] Offsite.

Table D.3.4-14. Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 1, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 121	1.5E-6	8.5E-12	4.5E-2	5.2E-6	2.9E-11	3.0E-2
Hanford	377645 / 1232	2.3E-6	4.7E-11	5.3E-1	7.7E-6	1.6E-10	4.5E-1
INEL	153061 / 3100	1.4E-6	1.8E-10	1.2	4.9E-6	6.0E-10	8.7E-1
LBL	5856829 / 1	9.8E-9	1.5E-13	1.8E-4	3.4E-8	5.0E-13	7.5E-9
LLNL	6324234 / 186	3.6E-6	5.9E-11	5.7E-2	1.3E-5	2.1E-10	2.0E-3
LANL	159152 / 1502	6.5E-5	6.9E-9	6.4E-1	2.2E-4	2.3E-8	5.0E-1
PGDP	500502 / 8	5.3E-9	5.9E-13	2.5E-3	1.8E-8	2.0E-12	1.7E-6
Mound	3032983 / 47	1.5E-6	8.6E-11	1.4E-2	5.1E-6	2.9E-10	4.7E-4
NTS	14266 / 137	1.5E-10	3.9E-14	4.2E-2	5.1E-10	1.3E-13	7.0E-4
RFETS	2171877 / 989	1.5E-5	2.0E-10	3.4E-1	5.1E-5	6.9E-10	2.7E-2
SNL-NM	610714 / 1	3.5E-9	1.4E-13	4.5E-4	1.2E-8	4.8E-13	2.1E-8
SRS	620618 / 1115	8.1E-5	7.7E-10	4.6E-1	2.8E-4	2.6E-9	3.1E-1
TOTAL		1.7E-4	6.9E-9	3.4	5.9E-4	2.3E-8	2.2

[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 ("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.
[d] Offsite.

Table D.3.4–15. Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 2, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 121	1.5E-6	8.5E-12	4.5E-2	5.2E-6	2.9E-11	3.0E-2
Hanford	377645 / 2184	4.5E-3	9.4E-8	8.1E-1	1.6E-2	3.2E-7	4.9E-1
INEL	153061 / 5364	7.3E-3	9.1E-7	1.8	2.5E-2	3.1E-6	8.3E-1
LBL	5856829 / 1	9.8E-9	1.5E-13	1.8E-4	3.4E-8	5.0E-13	7.5E-9
LLNL	6324234 / 186	3.6E-6	5.9E-11	5.7E-2	1.3E-5	2.1E-10	2.0E-3
LANL	159152 / 2772	6.4E-1	6.7E-5	9.6E-1	2.2	2.3E-4	4.8E-1
PGDP	500502 / 8	5.3E-9	5.9E-13	2.5E-3	1.8E-8	2.0E-12	1.7E-6
Mound	3032983 / 47	1.5E-6	8.6E-11	1.4E-2	5.1E-6	2.9E-10	4.7E-4
NTS	14266 / 137	1.5E-10	3.9E-14	4.2E-2	5.1E-10	1.3E-13	7.0E-4
RFETS	2171877 / 1852	1.1E-1	1.5E-6	5.7E-1	3.7E-1	5.0E-6	2.5E-2
SNL-NM	610714 / 1	3.5E-9	1.4E-13	4.5E-4	1.2E-8	4.8E-13	2.1E-8
SRS	620618 / 1896	2.6	2.4E-5	6.8E-1	8.8	8.2E-5	3.0E-1
TOTAL		3.3	6.7E-5	5.0	1.1E1	2.3E-4	2.1

[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 ("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.
[d] Offsite.

Table D.3.4-16. Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 3, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 121	1.5E-6	8.5E-12	4.5E-2	5.2E-6	2.9E-11	3.0E-2
Hanford	377645 / 2184	4.5E-3	9.4E-8	8.1E-1	1.6E-2	3.2E-7	4.9E-1
INEL	153061 / 6277	4.1E-2	5.1E-6	2.1	1.4E-1	1.7E-5	8.7E-1
LBL	5856829 / 1	9.8E-9	1.5E-13	1.8E-4	3.4E-8	5.0E-13	7.5E-9
LLNL	6324234 / 186	3.6E-6	5.9E-11	5.7E-2	1.3E-5	2.1E-10	2.0E-3
LANL	159152 / 713	7.1E-5	7.4E-9	3.8E-1	2.4E-4	2.5E-8	5.0E-1
PGDP	500502 / 8	5.3E-9	5.9E-13	2.5E-3	1.8E-8	2.0E-12	1.7E-6
Mound	3032983 / 47	1.5E-6	8.6E-11	1.4E-2	5.1E-6	2.9E-10	4.7E-4
NTS	14266 / 137	1.5E-10	3.9E-14	4.2E-2	5.1E-10	1.3E-13	7.0E-4
RFETS	2171877 / 420	1.2E-5	1.6E-10	1.6E-1	4.1E-5	5.6E-10	1.0E-1
SNL-NM	610714 / 1	3.5E-9	1.4E-13	4.5E-4	1.2E-8	4.8E-13	2.1E-8
SRS	620618 / 1896	2.6	2.4E-5	6.8E-1	8.8	8.2E-5	3.0E-1
TOTAL		2.6	2.4E-5	4.3	8.9	8.2E-5	2.3

[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 ("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.
[d] Offsite.

Table D.3.4–17. Risks Associated with Managing CH-TRUW Under the Centralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
WIPP	99889 / 6125	6.1E-1	1.6E-4	1.8	2.1	5.4E-4	2.3E-1
ANL-E	7939785 / 121	1.5E-6	8.5E-12	4.5E-2	5.2E-6	2.9E-11	3.0E-2
Hanford	377645 / 476	1.3E-6	2.7E-11	2.4E-1	4.4E-6	9.1E-11	3.3E-1
INEL	153061 / 1586	1.6E-6	2.0E-10	7.6E-1	5.3E-6	6.6E-10	8.5E-1
LBL	5856829 / 1	9.8E-9	1.5E-13	1.8E-4	3.4E-8	5.0E-13	7.5E-9
LLNL	6324234 / 186	3.6E-6	5.9E-11	5.7E-2	1.3E-5	2.1E-10	2.0E-3
LANL	159152 / 713	7.1E-5	7.4E-9	3.8E-1	2.4E-4	2.5E-8	5.0E-1
PGDP	500502 / 8	5.3E-9	5.9E-13	2.5E-3	1.8E-8	2.0E-12	1.7E-6
Mound	3032983 / 47	1.5E-6	8.6E-11	1.4E-2	5.1E-6	2.9E-10	4.7E-4
NTS	14266 / 137	1.5E-10	3.9E-14	4.2E-2	5.1E-10	1.3E-13	7.0E-4
RFETS	2171877 / 420	1.2E-5	1.6E-10	1.6E-1	4.1E-5	5.6E-10	1.0E-1
SNL-NM	610714 / 1	3.5E-9	1.4E-13	4.5E-4	1.2E-8	4.8E-13	2.1E-8
SRS	620618 / 416	6.4E-5	6.0E-10	2.2E-1	2.2E-4	2.0E-9	3.3E-1
TOTAL		6.1E-1	1.6E-4	3.7	2.1	5.4E-4	2.4

[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 ("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.
[d] Offsite.

Table D.3.4–18. CH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population At Each Installation, 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-7[b]	Pu-238 2.45E-7	Am-241 1.34E-9	Am-241 2.14E-6	Pu-239 2.53E-10	Pu-239 5.68E-7	Pu-238 0.00	Pu-242 0.00	Pu-242 0.00	Am-241 1.59E-6	Pu-242 0.00	Pu-238 1.32E-5		
Decentralized	Pu-239 1.37E-6	Pu-238 9.81E-7	Am-241 5.84E-7	Am-241 2.80E-5	Pu-239 3.25E-9	Pu-239 1.79E-6	Pu-238 8.38E-7	Pu-239 2.29E-10	Pu-239 1.82E-9	Am-241 4.94E-6	Pu-239 1.38E-9	Pu-238 4.85E-5	Pu-242 0.00	
Regionalized 1	Pu-239 1.18E-6	Pu-238 1.29E-6	Am-241 7.39E-7	Am-241 3.42E-5	Pu-239 5.11E-9	Pu-239 1.88E-6	Pu-238 1.50E-6	Pu-239 3.01E-10	Pu-239 2.76E-9	Am-241 7.94E-6	Pu-239 1.81E-9	Pu-238 7.81E-5		
Regionalized 2	Pu-239 1.18E-6	Pu-239 1.78E-3	Am-241 3.80E-3	Am-241 3.33E-1	Pu-239 5.11E-9	Pu-239 1.88E-6	Pu-238 1.50E-6	Pu-239 3.01E-10	Pu-239 2.76E-9	Am-241 5.82E-2	Pu-239 1.81E-9	Pu-238 2.47		
Regionalized 3	Pu-239 1.18E-6	Pu-239 1.78E-3	Am-241 2.13E-2	Am-241 3.68E-5	Pu-239 5.11E-9	Pu-239 1.88E-6	Pu-238 1.50E-6	Pu-239 3.01E-10	Pu-239 2.76E-9	Am-241 6.45E-6	Pu-239 1.81E-9	Pu-238 2.47		
Centralized	Pu-239 1.18E-6	Pu-238 9.02E-7	Am-241 8.11E-7	Am-241 3.68E-5	Pu-239 5.11E-9	Pu-239 1.88E-6	Pu-238 1.50E-6	Pu-239 3.01E-10	Pu-239 2.76E-9	Am-241 6.45E-6	Pu-239 1.81E-9	Pu-238 6.10E-5		Pu-238 5.19E-1

[a] Radionuclide contributing most risk.
[b] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this installation.

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 *Program-Wide 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 installations in existing or approved facilities. The program-wide risk of cancer fatality for this alternative is 2.3E-5 distributed over a total affected offsite population of approximately 19 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 0.61 to 3.3 estimated cancer fatalities over a total population of approximately 24 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 installations, respectively). Estimated program-wide cancer fatalities for all 12 installations in Regionalized 2 and 3 are 3.3 and 2.6, respectively, for a total offsite population of approximately 23 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 SRS, where, in both alternatives, 2.6 cancer fatalities in a population of 620,618 are estimated to occur over a 10-year treatment period. The higher estimated cancer risks at this installation are linked to its relatively large inventory of plutonium-238 (the larger the contaminant inventory with respect to other installations, 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 program-wide risk of cancer incidence due to exposure to carcinogenic chemicals remains fairly consistent (in the E-7 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 program-wide 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 program-wide risk to noninvolved worker populations (0.34 total estimated cancer fatalities); however, the estimated cancer fatality risk for Regionalized 3 (0.29) is only slightly lower than for Regionalized 2. The program-wide risk of cancer incidence due to exposure to carcinogenic chemicals is in the E-7 order of magnitude in all except No Action, where it is slightly lower (by approximately 1 order of magnitude).

Most-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-5 to E-4 range, and the highest risk of cancer fatality for an MEI is in the Centralized Alternative (1.9E-4 for the noninvolved worker MEI and 1.6E-4 for the offsite MEI). As discussed previously in this appendix, the EPA considers that risks of cancer incidence to an individual between 1.0E-4 and 1.0E-6 are within target risk levels (EPA, 1991b). In the alternatives involving treatment to LDRs (Regionalized 2, 3, and Centralized), the risks of cancer incidence to the noninvolved worker (Regionalized 2, 3, and Centralized) and offsite (Regionalized 2 and Centralized) MEIs from radionuclides exceed target risk levels.

Tables D.3.4–15 through D.3.4–17 show that the highest risks of cancer fatality to the offsite MEI are at SRS, LANL, and RFETS in Regionalized 2; SRS and INEL in Regionalized 3; and WIPP in the Centralized Alternative. The elevated risks to the MEIs at these installations are due to two factors. First, in Regionalized 2 and 3, elevated cancer risks to the MEIs at SRS, LANL, 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 7 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, program-wide 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 more than 1 order of magnitude (9.6E-3 estimated cancer fatalities over a population of 1,690 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 6E-1) 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 worst-case 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 3 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 (4.4), 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 except in the Centralized Alternative, where the highest risk to the offsite population is at WIPP. The radionuclides contributing the most risk to the offsite population at SRS 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 SRS's CH-TRUW at WIPP. Note that the cancer fatality risk to the offsite population is more than four times higher when SRS treats its own waste than when its waste is treated at WIPP. This reflects the larger size and higher density of the population surrounding SRS (compare the population distributions for SRS 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 installations are uranium-238 and uranium-235 at INEL via inhalation; and cesium-137 at Hanford and WIPP via external exposure.

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 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 installations 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 program-wide risks of cancer fatalities, cancer incidence, and genetic effects from radiation exposure associated with treatment to LDRs in Regionalized 2 are approximately 4 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 program-wide 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 two orders 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 worst-case

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, 3, 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 installation(s), respectively. As discussed above, the program-wide 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 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 installations such as SRS, INEL, and Hanford. Also, the population at only one installation, 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 exceed EPA target risk levels (offsite MEI cancer fatality risk 1.6E-4; noninvolved worker MEI cancer fatality risk 1.9E-4).

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Table D.3.4-19. Population Distribution Around SRS, Based on the 1990 U.S. Census

Direction from Installation	Distance from Installation										
	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	618.00	1,291.00	7,146.00	3,060.00	12,115.00
SSW	0.00	0.00	0.00	0.00	0.00	0.00	496.00	2,197.00	5,795.00	2,844.00	11,332.00
SW	0.00	0.00	0.00	0.00	0.00	0.00	1,283.00	6,379.00	898.00	2,077.00	10,637.00
WSW	0.00	0.00	0.00	0.00	0.00	4.00	1,201.00	3,580.00	1,491.00	6,157.00	12,433.00
W	0.00	0.00	0.00	0.00	0.00	45.00	6,431.00	7,295.00	3,050.00	8,251.00	25,072.00
WNW	0.00	0.00	0.00	0.00	0.00	1,980.00	2,529.00	141,404.00	32,376.00	16,308.00	194597.00
NW	0.00	0.00	0.00	0.00	0.00	475.00	14,925.00	87,876.00	6,296.00	2,327.00	111,899.00
NNW	0.00	0.00	0.00	0.00	0.00	786.00	18,188.00	11,409.00	7,099.00	2,700.00	40,182.00
N	0.00	0.00	0.00	0.00	0.00	3,137.00	21,804.00	10,819.00	6,626.00	10,148.00	52,534.00
NNE	0.00	0.00	0.00	0.00	0.00	12.00	1,431.00	1,777.00	3,117.00	15,556.00	21,893.00
NE	0.00	0.00	0.00	0.00	0.00	0.00	1,522.00	2,030.00	4,951.00	11,660.00	20,163.00
ENE	0.00	0.00	0.00	0.00	0.00	0.00	4,187.00	4,222.00	5,293.00	31,334.00	45,036.00
E	0.00	0.00	0.00	0.00	0.00	0.00	5,294.00	4,027.00	12,122.00	4,551.00	25,994.00
ESE	0.00	0.00	0.00	0.00	0.00	0.00	2,730.00	2,218.00	1,999.00	2,817.00	9,764.00
SE	0.00	0.00	0.00	0.00	0.00	0.00	593.00	5,773.00	5,699.00	11,579.00	23,644.00
SSE	0.00	0.00	0.00	0.00	0.00	0.00	179.00	482.00	551.00	2,111.00	3,323.00
Total	0.00	0.00	0.00	0.00	0.00	6,439.00	83,411.00	292,779.00	104,509.00	133,480.00	620618.00

Table D.3.4-20. Population Distribution Around the Waste Isolation Pilot Plant (WIPP), Based on the 1990 U.S. Census

Direction from Installation	Distance from Installation										
	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

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, and ORR. 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 five installations 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 installations will ship their wastes to regionalized or centralized consolidation installations 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, 1995b), as the two installations 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 installations 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
No Action Alternative	T[a]	T	T	T	T
No treatment; store at 5 installations	S[b]	S	S	S	S
Decentralized Alternative	T	T	T	T	T
Treat to WIPP-WAC and store at 5 installations	S	S	S	S	S
Regionalized Alternative 1		T			T
Treat to reduce gas and store at 2 installations		S			S
Regionalized Alternatives 2, 3, and Centralized Alternative		T			T
Treat to RCRA LDRs and store at 2 installations		S			S

[a] T—treatment installation.
[b] 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 5 installations	All installations	Generators store own waste
Decentralized Alternative Treat to WIPP-WAC and store at 5 installations	All installations	Generators treat and store own waste
Regionalized Alternative 1 Treat to minimize gas generation and store at 2 installations	Hanford, INEL/ANL-W[a], LANL, ORR, ANL-E	Hanford ORR
Regionalized Alternatives 2, 3, and Centralized Alternative Treat to RCRA LDRs and store at 2 installations	Hanford, INEL/ANL-W[a], LANL, ORR, ANL-E	Hanford 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*, program-wide 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 program-wide 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 Program-Wide Risks Associated with Routine Management of RH-TRUW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF[a]	CI[b]	CF	CI	CF	CI	C&OF[c]
No Action	8.8E-7	3.0E-6	3.7E-8	1.3E-7	1.7E-4	5.9E-4	8.6E-2
Decentralized	5.3E-6	1.8E-5	2.3E-7	8.2E-7	4.9E-3	1.7E-2	4.2E-1
Regionalized 1	5.6E-6	1.9E-5	2.4E-7	8.6E-7	5.1E-3	1.8E-2	4.2E-1
Regionalized 2, 3, and Centralized	5.2E-2	1.8E-1	1.8E-3	6.1E-3	9.3E-2	3.3E-1	8.5E-1

[a] CF—cancer fatality associated with radionuclide exposure.
[b] CI—cancer incidence associated with exposure to radionuclides and carcinogenic chemicals.
[c] 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	9,511,295	38,057	417
Decentralized	9,511,295	38,057	1,234
Regionalized 1	9,511,295	38,057	1,261
Regionalized 2, 3, and Centralized	9,511,295	38,057	2,544

Table D.3.4–25. Summary of Program-Wide Risks Associated with Routine Management of RH-TRUW: Risks To the Most-Exposed Offsite Individual and Most-Exposed Noninvolved Worker, by Alternative

Alternative	Offsite MEI				Noninvolved Worker MEI			
	CF[a]	Rad CI[b]	Chem CI[c]	HI[d]	CF	Rad CI	Chem CI	HI
No Action	1.5E-11	5.2E-11	4.0E-13	3.3E-12	5.8E-11	2.0E-10	2.5E-12	2.0E-11
Decentralized	8.8E-11	3.0E-10	8.1E-12	1.3E-10	3.4E-10	1.1E-9	5.0E-11	8.0E-10
Regionalized 1	9.3E-11	3.2E-10	8.1E-12	1.3E-10	3.5E-10	1.2E-9	5.0E-11	8.1E-10
Regionalized 2, 3, and Centralized	1.4E-6	4.8E-6	5.7E-12	1.9E-9	1.4E-6	4.8E-6	3.5E-11	1.2E-8

[a] CF—cancer fatality associated with exposure to radionuclides.
[b] Rad CI—cancer incidence associated with exposure to radionuclides.
[c] Chem CI—cancer incidence associated with exposure to carcinogenic chemicals.
[d] HI—hazard index associated with exposure to noncarcinogenic, toxic chemicals.

Table D.3.4-26. Program-Wide 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)	7.4E-5			
	Cancer Fatalities	3.7E-8			
	Cancer Incidence	1.3E-7	2.6E-9		
	Genetic Effects	7.4E-9			
Noninvolved Worker MEI	Dose (rem)	1.2E-7			
	Cancer Fatalities	5.8E-11			
	Cancer Incidence	2.0E-10	2.5E-12		
	Genetic Effects	1.2E-11			
	Hazard Index			2.0E-11	
Offsite Population	Dose (person-rem)	1.8E-3			
	Cancer Fatalities	8.8E-7			
	Cancer Incidence	3.0E-6	8.1E-9		
	Genetic Effects	1.8E-7			
Offsite MEI	Dose (rem)	3.0E-8			
	Cancer Fatalities	1.5E-11			
	Cancer Incidence	5.2E-11	4.0E-13		
	Genetic Effects	3.0E-12			
	Hazard Index			3.3E-12	
WM Workers	Dose (FTE-rem)	4.2E-1			
	Cancer Fatalities	1.7E-4			
	Cancer Incidence	5.9E-4	8.7E-8		
	Genetic Effects	2.5E-5			
	Exposure Index			3.0E-6	
	Construction Fatalities				3.5E-2
	Construction Injuries				1.5E1
	Operation Fatalities				5.1E-2
	Operation Injuries				4.3E1

Table D.3.4-27. Program-Wide 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)	4.5E-4			
	Cancer Fatalities	2.3E-7			
	Cancer Incidence	7.7E-7	5.2E-8		
	Genetic Effects	4.5E-8			
Noninvolved Worker MEI	Dose (rem)	6.7E-7			
	Cancer Fatalities	3.4E-10			
	Cancer Incidence	1.1E-9	5.0E-11		
	Genetic Effects	6.7E-11			
	Hazard Index			8.0E-10	
Offsite Population	Dose (person-rem)	1.1E-2			
	Cancer Fatalities	5.3E-6			
	Cancer Incidence	1.8E-5	1.6E-7		
	Genetic Effects	1.1E-6			
Offsite MEI	Dose (rem)	1.8E-7			
	Cancer Fatalities	8.8E-11			
	Cancer Incidence	3.0E-10	8.1E-12		
	Genetic Effects	1.8E-11			
	Hazard Index			1.3E-10	
WM Workers	Dose (FTE-rem)	1.2E1			
	Cancer Fatalities	4.9E-3			
	Cancer Incidence	1.7E-2	3.0E-6		
	Genetic Effects	7.3E-4			
	Exposure Index			3.0E-5	
	Construction Fatalities				2.7E-1
	Construction Injuries				1.2E2
	Operation Fatalities				1.5E-1
	Operation Injuries				1.3E2

Table D.3.4–28. Program-Wide Risks Associated with Treatment of RH-TRUW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	4.8E-4			
	Cancer Fatalities	2.4E-7			
	Cancer Incidence	8.1E-7	5.2E-8		
	Genetic Effects	4.8E-8			
Noninvolved Worker MEI	Dose (rem)	7.0E-7			
	Cancer Fatalities	3.5E-10			
	Cancer Incidence	1.2E-9	5.0E-11		
	Genetic Effects	7.0E-11			
	Hazard Index			8.1E-10	
Offsite Population	Dose (person-rem)	1.1E-2			
	Cancer Fatalities	5.6E-6			
	Cancer Incidence	1.9E-5	1.6E-7		
	Genetic Effects	1.1E-6			
Offsite MEI	Dose (rem)	1.9E-7			
	Cancer Fatalities	9.3E-11			
	Cancer Incidence	3.2E-10	8.1E-12		
	Genetic Effects	1.9E-11			
	Hazard Index			1.3E-10	
WM Workers	Dose (FTE-rem)	1.3E1			
	Cancer Fatalities	5.1E-3			
	Cancer Incidence	1.8E-2	3.4E-6		
	Genetic Effects	7.6E-4			
	Exposure Index			3.0E-5	
	Construction Fatalities				2.6E-1
	Construction Injuries				1.2E2
	Operation Fatalities				1.5E-1
	Operation Injuries				1.3E2

Table D.3.4-29. Program-Wide Risks Associated with Treatment of RH-TRUW Under the Regionalized 2, 3, and Centralized Alternatives, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	3.6			
	Cancer Fatalities	1.8E-3			
	Cancer Incidence	6.1E-3	3.7E-8		
	Genetic Effects	3.6E-4			
Noninvolved Worker MEI	Dose (rem)	2.8E-3			
	Cancer Fatalities	1.4E-6			
	Cancer Incidence	4.8E-6	3.5E-11		
	Genetic Effects	2.8E-7			
	Hazard Index			1.2E-8	
Offsite Population	Dose (person-rem)	1.0E2			
	Cancer Fatalities	5.2E-2			
	Cancer Incidence	1.8E-1	1.1E-7		
	Genetic Effects	1.0E-2			
Offsite MEI	Dose (rem)	2.8E-3			
	Cancer Fatalities	1.4E-6			
	Cancer Incidence	4.8E-6	5.7E-12		
	Genetic Effects	2.8E-7			
	Hazard Index			1.9E-9	
WM Workers	Dose (FTE-rem)	2.3E2			
	Cancer Fatalities	9.3E-2			
	Cancer Incidence	3.3E-1	5.2E-6		
	Genetic Effects	1.4E-2			
	Exposure Index			3.0E-5	
	Construction Fatalities				5.4E-1
	Construction Injuries				2.4E2
	Operation Fatalities				3.1E-1
	Operation Injuries				2.6E2

Table D.3.4–30. Risks Associated with Treatment of RH-TRUW Under the No Action Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 30	7.4E-8	4.1E-13	6.1E-3	2.5E-7	1.4E-12	1.0E-7
Hanford	377645 / 264	7.4E-7	1.5E-11	5.4E-2	2.5E-6	5.2E-11	5.8E-4
INEL	153061 / 77	4.1E-9	5.1E-13	1.6E-2	1.4E-8	1.7E-12	1.0E-5
LANL	159152 / 5	6.7E-10	7.0E-14	1.1E-3	2.3E-9	2.4E-13	3.5E-9
ORR	881652 / 41	6.6E-8	2.1E-12	8.4E-3	2.3E-7	7.4E-12	1.3E-6
TOTAL		8.8E-7	1.5E-11	8.6E-2	3.0E-6	5.2E-11	5.9E-4

[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 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.
[d] Offsite.

Table D.3.4–31. Risks Associated with Treatment of RH-TRUW Under the Decentralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 62	1.9E-7	1.1E-12	2.6E-2	6.5E-7	3.6E-12	5.8E-4
Hanford	377645 / 683	4.3E-6	8.8E-11	2.3E-1	1.5E-5	3.0E-10	2.7E-3
INEL	153061 / 168	1.2E-8	1.6E-12	5.9E-2	4.2E-8	5.3E-12	3.7E-3
LANL	159152 / 51	2.0E-8	2.1E-12	2.3E-2	6.7E-8	7.1E-12	4.8E-4
ORR	881652 / 270	8.0E-7	2.5E-11	9.3E-2	2.9E-6	9.2E-11	9.5E-3
TOTAL		5.3E-6	8.8E-11	4.3E-1	1.8E-5	3.0E-10	1.7E-2

[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 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.
[d] Offsite.

Table D.3.4–32. Risks Associated with Treatment of RH-TRUW Under the Regionalized Alternative 1, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 29	2.0E-7	1.1E-12	8.9E-3	6.9E-7	3.8E-12	5.2E-4
Hanford	377645 / 778	4.5E-6	9.3E-11	2.6E-1	1.5E-5	3.2E-10	3.5E-3
INEL	153061 / 105	1.6E-8	2.0E-12	3.3E-2	5.4E-8	6.7E-12	3.5E-3
LANL	159152 / 35	2.5E-8	2.6E-12	1.1E-2	8.5E-8	9.0E-12	4.6E-4
ORR	881652 / 314	8.3E-7	2.6E-11	1.1E-1	3.0E-6	9.5E-11	9.7E-3
TOTAL		5.6E-6	9.3E-11	4.2E-1	1.9E-5	3.2E-10	1.8E-2

[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 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.
[d] Offsite.

Table D.3.4–33. Risks Associated with Treatment of RH-TRUW Under the Regionalized 2, 3, and Centralized Alternatives, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
LANL	159152 / 35	2.5E-8	2.6E-12	1.1E-2	8.5E-8	9.0E-12	4.6E-4
ORR	881652 / 682	4.6E-2	1.4E-6	3.0E-1	1.6E-1	4.8E-6	3.2E-1
ANL-E	7939785 / 29	2.0E-7	1.1E-12	8.9E-3	6.9E-7	3.8E-12	5.2E-4
Hanford	377645 / 1693	6.3E-3	1.3E-7	5.9E-1	2.2E-2	4.5E-7	5.6E-3
INEL	153061 / 105	1.6E-8	2.0E-12	3.3E-2	5.4E-8	6.7E-12	3.5E-3
TOTAL		5.2E-2	1.4E-6	9.5E-1	1.8E-1	4.8E-6	3.3E-1

[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 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.
[d] Offsite.

Table D.3.4–34. RH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population at Each Installation, By Alternative

Alternative	Installation				
	ANL-E	Hanford	INEL	LANL	ORR
No Action	Pu-239[a] 3.13E-8[b]	Pu-238 4.31E-7	Pu-241 2.13E-9	Pu-239 3.53E-10	Cm-244 3.22E-8
Decentralized	Pu-239 8.02E-8	Pu-238 2.50E-6	Pu-241 6.64E-9	Pu-239 1.04E-8	Cm-244 3.75E-7
Regionalized 1	Pu-239 8.53E-8	Pu-238 2.51E-6	Pu-241 8.46E-9	Pu-239 1.31E-8	Cm-244 3.75E-7
Regionalized 2, 3, and Centralized	Pu-239 8.53E-8	Pu-241 2.57E-3	Pu-241 8.46E-9	Pu-239 1.31E-8	Cm-244 2.11E-2

[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 installation.

D.3.4.7 Results of the RH-TRUW Human Health Risk Analysis

D.3.4.7.1 *Program-Wide 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 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 five generator installations in existing or approved facilities. The program-wide risk of cancer fatality for this alternative is 8.8E-7 distributed over a total affected offsite population of approximately 9.5 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 five installations) and Regionalized 1 (in which wastes are treated to reduce gas generation and stored at two installations) 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 installations (Regionalized 2, 3, and Centralized Alternatives) results in markedly higher risks to offsite populations than in the other alternatives, with 5.2E-2 estimated cancer fatalities over a total population of approximately 9.5 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-2 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 installation are linked to its relatively large inventory of curium-244 (the larger the contaminant inventory with respect to other installations, the larger the amount of contaminant assumed to be released during treatment).

Estimated program-wide risks of cancer incidence from exposure to carcinogenic chemicals remain fairly consistent across alternatives, in the E-7 order of magnitude in all alternatives except No Action, in which cancer incidence risk is 8.1E-9 for the offsite population.

Noninvolved Worker Population. The program-wide health risks to noninvolved worker populations parallel the trends observed for offsite populations but are slightly lower and involve a smaller affected population of 38,052 (see Table D.3.4–24). Treatment of RH-TRUW to LDRs and storage at two installations (Regionalized 2, 3, and Centralized Alternatives) poses the highest program-wide risk to noninvolved worker populations (1.8E-3 total estimated cancer fatalities). The risk of cancer incidence due to exposure to carcinogenic chemicals is in the E-8 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).

Most-Exposed Noninvolved Worker and Most-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 approximately 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. Program-wide radiological risks to workers are lowest in No Action (1.7E-4 estimated cancer fatalities over a population of 417 FTEs), somewhat higher in Decentralized and Regionalized 1 (approximately 5E-3 in both alternatives), and increase almost to the E-1 order of magnitude in the other alternatives.

Worker health risks associated with chemical exposure vary slightly among alternatives. The exposure index, or worst-case 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-238 at Hanford in No Action, Decentralized, and Regionalized 1; plutonium-241 at Hanford in Regionalized 2, 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 only slightly lower 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 five 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 the Regionalized 1 Alternative with the Regionalized 2, 3, and Centralized Alternatives: Treatment to Reduce Gas Generation Versus Treatment to 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 program-wide 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 4 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 worst-case 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 program-wide 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 TRUW Accidents

At the time of this writing the analyses for postulated TRUW facility accidents were incomplete. Current safety analysis reports (as developed in accordance with DOE Order 5481.1B, *Safety Analysis and Review System*) and site-specific DOE environmental impact statements contain predictions of the consequences and frequency of occurrence of selected waste storage accident scenarios. A brief summary of some of the accident scenarios from these safety analysis reports and environmental impact statements, the assumptions used by the various sites in preparing their analyses, and the estimated release or health effects are presented in Appendix F. The PEIS analyses for TRUW storage accidents can be expected to use similar assumptions and produce similar results. TRUW treatment-related accident scenarios will be similar to those analyzed for LLW and LLMW. Accidents associated with contact-handled TRUW will be analyzed similarly to contact-handled LLW and LLMW. These storage and treatment accident results will be published in a supplement to this draft PEIS and will be included in the final PEIS.

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 non-alpha LLMW) and polychlorinated biphenyls (PCBs) (e.g., PCB LLMW or non-PCB LLMW).

More than 50 installations within the DOE complex generate LLMW; following are the installations considered in this portion of the PEIS (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
- 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

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, 1995e) provide more detailed information on this waste, including LLMW inventories at DOE installations, 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 installations 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 installations treat CH-LLMW and 15 installations dispose of it.
- The Regionalized Alternatives: Regionalized 1 involves treatment of CH-LLMW at 11 installations and disposal at 12. In Regionalized 2 and 3, CH-LLMW is treated at seven installations and disposed of at six and one installation(s), respectively. Regionalized 4 entails treating CH-LLMW at four installations 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 installations 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 installations, 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, 1995e).

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.

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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[a]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	Store at all	S[b]	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[c]	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						

[a] T—treatment installation.
[b] S—storage installation.
[c] D—disposal installation.

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), 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 installations west of the Mississippi River and tumulus (above-ground vault) disposal will be used at eastern installations. 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 installation 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 an installation is postulated to possess PCB-LLMW, the source term for that mixed waste is combined with all the other LLMW source terms for that installation.

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*, program-wide 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.
- Table D.3.5-3 presents an overview, by alternative, of the program-wide 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 heath effects to the 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 installation and alternative.

The following tables are located at the end of Section D.3.5.4:

- Tables D.3.5-7 through D.3.5-14 provide more detailed information on the program-wide 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 installation.
- Tables D.3.5-23 through D.3.5-29 provide more detailed information on the program-wide 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 most exposed, by installation.

Table D.3.5-2. Summary of Program-Wide Risks Associated with Treatment of LLMW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF[a]	CI[b]	CF	CI	CF	CI	C&OF[c]
No Action	3.1E-1	1.1	1.3E-2	4.3E-2	8.7E-1	3.1	1.8
Decentralized	1.7E-1	5.8E-1	2.4E-3	8.0E-3	5.2E-1	1.8	4.0
Regionalized 1	1.6E-1	5.5E-1	2.4E-3	8.0E-3	5.7E-1	2.0	3.7
Regionalized 2	1.8E-2	6.1E-2	3.6E-4	1.2E-3	5.8E-1	2.0	3.4
Regionalized 3	1.8E-2	6.1E-2	3.6E-4	1.2E-3	5.8E-1	2.0	3.4
Regionalized 4	1.8E-2	5.9E-2	3.6E-4	1.2E-3	6.3E-1	2.2	3.1
Centralized	2.5E-2	8.6E-2	3.3E-4	1.1E-3	6.4E-1	2.2	2.6
RH-LLMW	1.3E-3	4.5E-3	4.2E-5	1.4E-4	2.3E-2	8.1E-2	4.5E-1

[a] CF—cancer fatality associated with radionuclide exposure.
[b] CI—cancer incidence associated with exposure to radionuclides and carcinogenic chemicals.
[c] C&OF—fatalities due to the physical hazards of constructing and operating waste management facilities.

Table D.3.5-3. Summary of Program-Wide 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[a]	Rad CI[b]	Chem CI[c]	HI[d]	CF	Rad CI	Chem CI	CF	CI	C&OF[e]
Decentralized	1.8E-3	6.1E-3	1.1E-2	3.0	5.0E-2	1.7E-1	5.0E-1	5.5E-1	1.9	4.8E-1
Regionalized 1	1.2E-3	4.1E-3	1.0E-2	3.0	2.4E-2	8.0E-2	5.0E-1	5.5E-1	1.9	4.5E-1
Regionalized 2	1.4E-3	4.8E-3	1.3E-2	2.7	2.4E-2	8.0E-2	8.3E-1	5.2E-1	1.8	4.2E-1
Regionalized 3	0.00	0.00	2.8E-3	3.1E-1	0.00	0.00	5.4E-2	3.7E-1	1.3	1.8E-1
Regionalized 4	1.5E-3	5.1E-3	1.3E-2	2.7	2.5E-2	8.5E-2	8.2E-1	6.4E-1	2.2	4.1E-1
Centralized	1.9E-2	6.6E-2	9.5E-4	2.4	2.5E-1	8.6E-1	8.5E-3	3.6E-1	1.3	1.5E-1
RH-LLMW	8.5E-5	2.9E-4	1.4E-5	1.3E-2	1.3E-3	4.5E-3	5.8E-4	1.5E-3	5.2E-3	3.0E-2

[a] CF—Risk of cancer fatality associated with exposure to both radionuclides and carcinogenic chemicals.
[b] Rad CI—Risk of cancer incidence associated with exposure to radionuclides.
[c] Chem CI—Risk of cancer incidence associated with exposure to chemical carcinogens.
[d] HI—Hazard Index.
[e] 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	38,499,644	113,752	9,218
Decentralized	38,499,644	113,752	15,082
Regionalized 1	38,499,644	113,752	14,052
Regionalized 2	38,499,644	113,752	13,300
Regionalized 3	38,499,644	113,752	13,300
Regionalized 4	38,499,644	113,752	12,031
Centralized	38,499,644	113,752	9,756
RH-LLMW	2,032,976	36,930	1,312

Table D.3.5–5. Summary of Program-Wide Risks Associated with Treatment of LLMW: Risks To the Offsite and Noninvolved Worker Most-Exposed Individuals, by Alternative

Alternative	Offsite MEI[a]				Noninvolved Worker MEI[a]			
	CF[b]	Rad CI[c]	Chem CI[d]	HI[e]	CF	Rad CI	Chem CI	HI
No Action	7.0E-6	2.4E-5	2.0E-8	2.3E-5	8.7E-6	3.0E-5	2.1E-7	4.5E-5
Decentralized	2.5E-6	8.5E-6	1.2E-9	1.4E-6	7.3E-7	2.5E-6	7.1E-9	8.8E-6
Regionalized 1	2.6E-6	8.7E-6	1.0E-9	1.4E-6	7.4E-7	2.5E-6	6.2E-9	8.7E-6
Regionalized 2	2.7E-7	9.2E-7	1.0E-9	1.4E-6	3.1E-7	1.0E-6	6.2E-9	8.8E-6
Regionalized 3	2.7E-7	9.2E-7	1.0E-9	1.4E-6	3.1E-7	1.0E-6	6.2E-9	8.8E-6
Regionalized 4	2.7E-7	9.3E-7	1.5E-9	2.0E-6	3.1E-7	1.1E-6	9.3E-9	1.3E-5
Centralized	5.2E-7	1.8E-6	4.1E-10	4.5E-7	5.8E-7	2.0E-6	1.4E-8	1.6E-5
RH-LLMW	3.4E-8	1.2E-7	2.9E-12	4.8E-9	2.3E-8	7.8E-8	1.8E-11	3.8E-8

[a] MEI—Most-exposed individual.
[b] CF—Risk of cancer fatality associated with exposure to radionuclides.
[c] Rad CI—Risk of cancer incidence associated with exposure to radionuclides.
[d] Chem CI—Risk of cancer incidence associated with exposure to chemical carcinogens.
[e] 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 Installation

Alt.[a]	Installation																			
	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[b] 1.24E-2[c]	Pu-238 1.11E-2	Pu-238 3.85E-4	Co-60 4.87E-4	Co-60 4.61E-6	Pu-238 8.81E-5	U-238 3.45E-5	Pu-238 7.55E-4	U-238 7.81E-11	U-238 1.09E-1	Pu-238 1.45E-6	U-238 5.92E-5	U-238 3.32E-3	Pu-238 1.63E-2	Pu-238 3.13E-5	H-3 2.60E-3	Pu-238 2.03E-4	U-238 5.90E-4	U-238 1.08E-4	Pu-238 1.38E-5
Dec.	U-238 5.94E-4	Pu-238 9.84E-4	H-3 3.50E-5	H-3 1.98E-4	H-3 2.30E-6	H-3 5.86E-4	H-3 1.02E-2	H-3 1.54E-1	U-238 1.75E-14	U-238 4.86E-4	H-3 3.41E-5	U-238 2.49E-6	U-238 1.10E-4	Pu-238 4.09E-5	H-3 1.30E-4	H-3 1.68E-3	Pu-238 1.08E-7	U-238 2.39E-5	U-238 5.32E-6	H-3 1.26E-4
Reg. 1	U-238 2.77E-6	Pu-238 9.03E-4	H-3 3.50E-5	Co-60 1.05E-7	Co-60 9.90E-10	H-3 6.02E-4	U-238 7.74E-9	H-3 1.57E-1	U-238 1.75E-14	U-238 4.19E-4	H-3 3.41E-5	H-3 3.03E-5	U-238 1.10E-4	Pu-238 4.08E-5	Pu-238 7.30E-9	H-3 1.68E-3	H-3 1.06E-7	U-238 3.30E-4	U-238 2.43E-8	Pu-238 3.22E-9
Reg. 2	U-238 2.77E-6	H-3 1.20E-2	H-3 6.10E-4	Co-60 1.05E-7	Co-60 9.90E-10	H-3 8.52E-4	U-238 7.74E-9	Pu-238 1.76E-7	U-238 1.75E-14	U-238 6.56E-4	H-3 2.34E-6	H-3 3.15E-5	U-238 7.48E-7	Pu-238 4.09E-5	Pu-238 7.30E-9	H-3 1.68E-3	H-3 1.06E-7	U-238 1.33E-7	U-238 2.43E-8	Pu-238 3.22E-9
Reg. 3	U-238 2.77E-6	H-3 1.20E-2	H-3 6.10E-4	Co-60 1.05E-7	Co-60 9.90E-10	H-3 8.52E-4	U-238 7.74E-9	Pu-238 1.76E-7	U-238 1.75E-14	U-238 6.56E-4	H-3 2.34E-6	H-3 3.15E-5	U-238 7.48E-7	Pu-238 4.09E-5	Pu-238 7.30E-9	H-3 1.68E-3	H-3 1.06E-7	U-238 1.33E-7	U-238 2.43E-8	Pu-238 3.22E-9
Reg. 4	U-238 2.77E-6	H-3 1.20E-2	H-3 6.51E-4	Co-60 1.05E-7	Co-60 9.90E-10	H-3 3.79E-5	U-238 7.74E-9	Pu-238 1.76E-7	U-238 1.75E-14	U-238 8.04E-4	H-3 2.34E-6	U-238 1.65E-8	U-238 7.48E-7	Pu-238 8.15E-7	Pu-238 7.30E-9	H-3 1.68E-3	H-3 1.06E-7	U-238 1.33E-7	U-238 2.43E-8	Pu-238 3.24E-9
Cen.	U-238 2.77E-6	H-3 2.30E-2	H-3 4.83E-6	Co-60 1.05E-7	Co-60 9.90E-10	H-3 3.79E-5	U-238 7.74E-9	Pu-238 1.76E-7	U-238 1.75E-14	U-238 2.18E-6	H-3 2.34E-6	U-238 1.65E-8	U-238 7.48E-7	Pu-238 8.15E-7	Pu-238 7.30E-9	H-3 9.81E-7	H-3 1.06E-7	U-238 1.33E-7	U-238 2.43E-8	Pu-238 3.24E-9
RH		Pu-238 3.08E-7	H-3 1.95E-4							H-3 7.66E-4						H-3 2.80E-5				

[a] Alternative abbreviations are: Alt. = Alternative; Dec. = Decentralized; Reg. = Regionalized; Cen. = Centralized; RH = RH-LLMW.
[b] Radionuclide contributing most risk.
[c] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this installation.

Table D.3.5–7. Program-Wide 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)	2.5E1			
	Cancer Fatalities	1.3E-2			
	Cancer Incidence	4.3E-2	5.8E-4		
	Genetic Effects	2.5E-3			
Noninvolved Worker MEI	Dose (rem)	1.7E-2			
	Cancer Fatalities	8.7E-6			
	Cancer Incidence	3.0E-5	2.1E-7		
	Genetic Effects	1.7E-6			
	Hazard Index			4.5E-5	
Offsite Population	Dose (person-rem)	6.2E2			
	Cancer Fatalities	3.1E-1			
	Cancer Incidence	1.1	2.9E-3		
	Genetic Effects	6.2E-2			
Offsite MEI	Dose (rem)	1.4E-2			
	Cancer Fatalities	7.0E-6			
	Cancer Incidence	2.4E-5	2.0E-8		
	Genetic Effects	1.4E-6			
	Hazard Index			2.3E-5	
WM Workers	Dose (FTE-rem)	2.2E3			
	Cancer Fatalities	8.7E-1			
	Cancer Incidence	3.0	1.1E-2		
	Genetic Effects	1.3E-1			
	Exposure Index			1.2E-2	
	Construction Fatalities				6.2E-1
	Construction Injuries				2.7E2
	Operation Fatalities				1.1
	Operation Injuries				9.7E2

Table D.3.5–8. Program-Wide 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-3			
	Cancer Incidence	8.0E-3	1.4E-5		
	Genetic Effects	4.7E-4			
Noninvolved Worker MEI	Dose (rem)	1.5E-3			
	Cancer Fatalities	7.3E-7			
	Cancer Incidence	2.5E-6	7.1E-9		
	Genetic Effects	1.5E-7			
	Hazard Index			8.8E-6	
Offsite Population	Dose (person-rem)	3.4E2			
	Cancer Fatalities	1.7E-1			
	Cancer Incidence	5.8E-1	6.2E-5		
	Genetic Effects	3.4E-2			
Offsite MEI	Dose (rem)	5.0E-3			
	Cancer Fatalities	2.5E-6			
	Cancer Incidence	8.5E-6	1.2E-9		
	Genetic Effects	5.0E-7			
	Hazard Index			1.4E-6	
WM Workers	Dose (FTE-rem)	1.3E3			
	Cancer Fatalities	5.2E-1			
	Cancer Incidence	1.8	9.9E-3		
	Genetic Effects	7.8E-2			
	Exposure Index			1.2E-2	
	Construction Fatalities				2.2
	Construction Injuries				9.4E2
	Operation Fatalities				1.9
	Operation Injuries				1.6E3

Table D.3.5-9. Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	4.7			
	Cancer Fatalities	2.4E-3			
	Cancer Incidence	8.0E-3	1.3E-5		
	Genetic Effects	4.7E-4			
Noninvolved Worker MEI	Dose (rem)	1.5E-3			
	Cancer Fatalities	7.4E-7			
	Cancer Incidence	2.5E-6	6.2E-9		
	Genetic Effects	1.5E-7			
	Hazard Index			8.7E-6	
Offsite Population	Dose (person-rem)	3.3E2			
	Cancer Fatalities	1.6E-1			
	Cancer Incidence	5.5E-1	4.6E-5		
	Genetic Effects	3.3E-2			
Offsite MEI	Dose (rem)	5.1E-3			
	Cancer Fatalities	2.6E-6			
	Cancer Incidence	8.7E-6	1.0E-9		
	Genetic Effects	5.1E-7			
	Hazard Index			1.4E-6	
WM Workers	Dose (FTE-rem)	1.4E3			
	Cancer Fatalities	5.7E-1			
	Cancer Incidence	2.0	9.2E-3		
	Genetic Effects	8.5E-2			
	Exposure Index			1.2E-2	
	Construction Fatalities				2.0
	Construction Injuries				8.6E2
	Operation Fatalities				1.7
	Operation Injuries				1.5E3

Table D.3.5-10. Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	7.2E-1			
	Cancer Fatalities	3.6E-4			
	Cancer Incidence	1.2E-3	1.5E-5		
	Genetic Effects	7.2E-5			
Noninvolved Worker MEI	Dose (rem)	6.1E-4			
	Cancer Fatalities	3.1E-7			
	Cancer Incidence	1.0E-6	6.2E-9		
	Genetic Effects	6.1E-8			
	Hazard Index			8.8E-6	
Offsite Population	Dose (person-rem)	3.6E1			
	Cancer Fatalities	1.8E-2			
	Cancer Incidence	6.1E-2	3.8E-5		
	Genetic Effects	3.6E-3			
Offsite MEI	Dose (rem)	5.4E-4			
	Cancer Fatalities	2.7E-7			
	Cancer Incidence	9.2E-7	1.0E-9		
	Genetic Effects	5.4E-8			
	Hazard Index			1.4E-6	
WM Workers	Dose (FTE-rem)	1.4E3			
	Cancer Fatalities	5.8E-1			
	Cancer Incidence	2.0	9.6E-3		
	Genetic Effects	8.6E-2			
	Exposure Index			1.3E-2	
	Construction Fatalities				1.8
	Construction Injuries				7.7E2
	Operation Fatalities				1.6
	Operation Injuries				1.4E3

Table D.3.5-11. Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	7.2E-1			
	Cancer Fatalities	3.6E-4			
	Cancer Incidence	1.2E-3	1.2E-5		
	Genetic Effects	7.2E-5			
Noninvolved Worker MEI	Dose (rem)	6.1E-4			
	Cancer Fatalities	3.1E-7			
	Cancer Incidence	1.0E-6	6.2E-9		
	Genetic Effects	6.1E-8			
	Hazard Index			8.8E-6	
Offsite Population	Dose (person-rem)	3.6E1			
	Cancer Fatalities	1.8E-2			
	Cancer Incidence	6.1E-2	3.2E-5		
	Genetic Effects	3.6E-3			
Offsite MEI	Dose (rem)	5.4E-4			
	Cancer Fatalities	2.7E-7			
	Cancer Incidence	9.2E-7	1.0E-9		
	Genetic Effects	5.4E-8			
	Hazard Index			1.4E-6	
WM Workers	Dose (FTE-rem)	1.4E3			
	Cancer Fatalities	5.8E-1			
	Cancer Incidence	2.0	9.6E-3		
	Genetic Effects	8.6E-2			
	Exposure Index			1.3E-2	
	Construction Fatalities				1.8
	Construction Injuries				7.7E2
	Operation Fatalities				1.6
	Operation Injuries				1.4E3

Table D.3.5-12. Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	7.1E-1			
	Cancer Fatalities	3.6E-4			
	Cancer Incidence	1.2E-3	1.3E-5		
	Genetic Effects	7.1E-5			
Noninvolved Worker MEI	Dose (rem)	6.3E-4			
	Cancer Fatalities	3.1E-7			
	Cancer Incidence	1.1E-6	9.3E-9		
	Genetic Effects	6.3E-8			
	Hazard Index			1.3E-5	
Offsite Population	Dose (person-rem)	3.5E1			
	Cancer Fatalities	1.8E-2			
	Cancer Incidence	5.9E-2	3.4E-5		
	Genetic Effects	3.5E-3			
Offsite MEI	Dose (rem)	5.5E-4			
	Cancer Fatalities	2.7E-7			
	Cancer Incidence	9.3E-7	1.5E-9		
	Genetic Effects	5.5E-8			
	Hazard Index			2.0E-6	
WM Workers	Dose (FTE-rem)	1.6E3			
	Cancer Fatalities	6.3E-1			
	Cancer Incidence	2.2	1.2E-2		
	Genetic Effects	9.5E-2			
	Exposure Index			1.6E-2	
	Construction Fatalities				1.6
	Construction Injuries				6.9E2
	Operation Fatalities				1.5
	Operation Injuries				1.3E3

Table D.3.5–13. Program-Wide Risks Associated with Treatment of LLMW Under the Centralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	6.6E-1			
	Cancer Fatalities	3.3E-4			
	Cancer Incidence	1.1E-3	7.9E-6		
	Genetic Effects	6.6E-5			
Noninvolved Worker MEI	Dose (rem)	1.2E-3			
	Cancer Fatalities	5.8E-7			
	Cancer Incidence	2.0E-6	1.4E-8		
	Genetic Effects	1.2E-7			
	Hazard Index			1.6E-5	
Offsite Population	Dose (person-rem)	5.0E1			
	Cancer Fatalities	2.5E-2			
	Cancer Incidence	8.6E-2	1.5E-5		
	Genetic Effects	5.0E-3			
Offsite MEI	Dose (rem)	1.0E-3			
	Cancer Fatalities	5.2E-7			
	Cancer Incidence	1.8E-6	4.1E-10		
	Genetic Effects	1.0E-7			
	Hazard Index			4.5E-7	
WM Workers	Dose (FTE-rem)	1.6E3			
	Cancer Fatalities	6.4E-1			
	Cancer Incidence	2.2	1.8E-2		
	Genetic Effects	9.6E-2			
	Exposure Index			2.6E-2	
	Construction Fatalities				1.4
	Construction Injuries				6.0E2
	Operation Fatalities				1.2
	Operation Injuries				1.0E3

Table D.3.5-14. Program-Wide Risks Associated with Treatment of RH-LLMW Under Each Alternative (Except No Action), by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	8.4E-2			
	Cancer Fatalities	4.2E-5			
	Cancer Incidence	1.4E-4	3.9E-8		
	Genetic Effects	8.4E-6			
Noninvolved Worker MEI	Dose (rem)	4.6E-5			
	Cancer Fatalities	2.3E-8			
	Cancer Incidence	7.8E-8	1.8E-11		
	Genetic Effects	4.6E-9			
	Hazard Index			3.8E-8	
Offsite Population	Dose (person-rem)	2.7			
	Cancer Fatalities	1.3E-3			
	Cancer Incidence	4.5E-3	7.2E-8		
	Genetic Effects	2.7E-4			
Offsite MEI	Dose (rem)	6.8E-5			
	Cancer Fatalities	3.4E-8			
	Cancer Incidence	1.2E-7	2.9E-12		
	Genetic Effects	6.8E-9			
	Hazard Index			4.8E-9	
WM Workers	Dose (FTE-rem)	5.8E1			
	Cancer Fatalities	2.3E-2			
	Cancer Incidence	8.1E-2	6.7E-5		
	Genetic Effects	3.5E-3			
	Exposure Index			4.6E-4	
	Construction Fatalities				2.9E-1
	Construction Injuries				1.3E2
	Operation Fatalities				1.6E-1
	Operation Injuries				1.4E2

Table D.3.5–15. Risks Associated with Treatment of LLMW Under the No Action Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
FEMP	2764589 / 268	6.3E-4	1.2E-8	5.2E-2	2.2E-3	4.3E-8	2.2E-3
KAPL–K	1290172 / 21	1.2E-3	2.6E-8	6.6E-3	3.9E-3	8.7E-8	9.0E-3
LBL	5856829 / 18	4.3E-5	6.5E-10	3.6E-3	1.6E-4	2.4E-9	1.5E-4
LANL	159152 / 221	1.5E-4	1.6E-8	4.4E-2	5.2E-4	5.5E-8	7.7E-3
LLNL	6324234 / 329	1.9E-3	3.1E-8	6.5E-2	6.6E-3	1.1E-7	6.5E-3
Mound	3032983 / 11	2.5E-5	1.5E-9	2.1E-3	8.8E-5	5.0E-9	8.7E-5
NTS	14266 / 0	3.2E-11	8.0E-15	4.4E-5	1.1E-10	2.8E-14	1.8E-6
Pantex	265185 / 74	2.2E-6	1.8E-10	1.5E-2	7.7E-6	6.4E-10	1.5E-3
Ports	639602 / 534	6.4E-5	8.0E-9	1.1E-1	3.3E-4	4.7E-8	5.7E-3
SNL–NM	610714 / 12	7.7E-5	3.0E-9	2.4E-3	2.6E-4	1.0E-8	1.8E-4
Hanford	377645 / 585	1.5E-2	3.1E-7	2.5E-1	5.2E-2	1.1E-6	4.5E-1
RFETS	2171877 / 931	2.6E-2	3.6E-7	2.1E-1	9.2E-2	1.2E-6	7.8E-3
WVDP	1698391 / 15	2.7E-4	4.1E-9	2.9E-3	9.3E-4	1.4E-8	2.4E-4
KCP	1729833 / 1	1.1E-5	5.0E-10	1.2E-4	3.7E-5	1.7E-9	7.9E-6
SRS	620618 / 1358	3.1E-3	2.9E-8	4.6E-1	1.1E-2	1.0E-7	7.9E-1
ORR	881652 / 3072	2.3E-1	7.0E-6	8.2E-1	7.8E-1	2.4E-5	9.5E-1
PGDP	500502 / 89	3.6E-3	4.0E-7	1.7E-2	1.2E-2	1.4E-6	1.3E-3
INEL	153061 / 1156	1.1E-3	1.4E-7	4.1E-1	3.8E-3	4.8E-7	6.5E-1
BNL	5738554 / 39	2.3E-4	3.1E-9	7.6E-3	7.9E-4	1.1E-8	5.2E-4
ANL-E	7939785 / 484	2.6E-2	1.4E-7	1.4E-1	8.9E-2	4.9E-7	1.6E-1
TOTAL		3.1E-1	7.0E-6	2.6	1.1	2.4E-5	3.1

[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 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.
[d] Offsite.

Table D.3.5–16. Risks Associated with Treatment of LLMW Under the Decentralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
BNL	5738554 / 62	1.2E-5	1.6E-10	1.6E-2	4.1E-5	5.5E-10	4.3E-4
FEMP	2764589 / 533	2.6E-5	4.9E-10	1.6E-1	9.1E-5	1.7E-9	1.1E-3
KAPL-K	1290172 / 44	3.0E-4	6.7E-9	1.3E-2	1.0E-3	2.3E-8	6.2E-3
LBL	5856829 / 40	1.0E-2	1.6E-7	1.0E-2	3.5E-2	5.5E-7	1.3E-4
LANL	159152 / 590	5.9E-4	6.2E-8	2.0E-1	2.0E-3	2.1E-7	5.5E-3
LLNL	6324234 / 831	1.5E-1	2.5E-6	2.7E-1	5.2E-1	8.5E-6	2.8E-2
ORR	881652 / 2530	1.1E-3	3.3E-8	7.7E-1	3.7E-3	1.2E-7	6.2E-1
Mound	3032983 / 7	1.3E-4	7.4E-9	2.1E-3	4.3E-4	2.5E-8	4.7E-5
NTS	14266 / 0	7.0E-15	0.00	2.4E-5	1.8E-9	4.8E-13	9.1E-7
Pantex	265185 / 145	3.5E-5	2.9E-9	3.9E-2	1.2E-4	1.0E-8	1.2E-3
Ports	639602 / 1853	2.7E-6	3.4E-10	4.8E-1	1.2E-5	1.5E-9	5.6E-3
SNL-NM	610714 / 20	1.4E-4	5.4E-9	5.4E-3	4.7E-4	1.9E-8	1.2E-3
SRS	620618 / 1289	1.7E-3	1.7E-8	4.3E-1	5.9E-3	5.6E-8	3.7E-1
RFETS	2171877 / 2305	6.7E-5	9.1E-10	6.3E-1	2.3E-4	3.1E-9	4.1E-3
WVDP	1698391 / 11	2.5E-7	3.8E-12	6.8E-3	8.6E-7	1.3E-11	8.6E-3
KCP	1729833 / 1	3.9E-6	1.8E-10	2.6E-4	1.3E-5	6.0E-10	1.2E-4
INEL	153061 / 1588	5.2E-5	6.5E-9	5.3E-1	1.8E-4	2.2E-8	3.6E-1
Hanford	377645 / 2196	1.5E-3	3.0E-8	6.2E-1	5.0E-3	1.0E-7	3.6E-1
PGDP	500502 / 144	1.2E-4	1.3E-8	4.7E-2	4.1E-4	4.5E-8	8.4E-4
ANL-E	7939785 / 886	1.3E-3	7.2E-9	2.3E-1	4.5E-3	2.5E-8	6.7E-2
TOTAL		1.7E-1	2.5E-6	4.5	5.8E-1	8.5E-6	1.8

[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 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.
[d] Offsite.

Table D.3.5–17. Risks Associated with Treatment of LLMW Under the Regionalized Alternative 1, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
BNL	5738554 / 16	5.2E-8	7.0E-13	4.0E-3	1.9E-7	2.5E-12	2.0E-4
FEMP	2764589 / 1233	7.0E-4	1.3E-8	3.5E-1	2.4E-3	4.5E-8	9.5E-2
KAPL-K	1290172 / 9	2.6E-7	5.8E-12	2.8E-3	8.9E-7	2.0E-11	2.2E-3
LBL	5856829 / 8	9.8E-9	1.5E-13	1.9E-3	4.9E-8	8.3E-13	7.4E-5
LANL	159152 / 597	6.1E-4	6.4E-8	2.0E-1	2.1E-3	2.2E-7	6.4E-3
LLNL	6324234 / 915	1.6E-1	2.6E-6	3.1E-1	5.3E-1	8.7E-6	8.1E-2
ORR	881652 / 2162	9.3E-4	2.9E-8	5.9E-1	3.2E-3	9.8E-8	3.9E-1
Mound	3032983 / 5	5.9E-9	3.4E-13	1.1E-3	7.3E-8	2.9E-12	4.3E-5
NTS	14266 / 1	7.0E-15	0.00	1.2E-4	1.8E-9	4.8E-13	1.6E-5
Pantex	265185 / 145	3.5E-5	2.9E-9	3.9E-2	1.2E-4	1.0E-8	1.2E-3
Ports	639602 / 1353	4.9E-5	6.0E-9	4.0E-1	1.7E-4	2.1E-8	2.1E-1
SNL-NM	610714 / 5	1.8E-8	7.1E-13	1.2E-3	6.1E-8	2.4E-12	6.1E-5
SRS	620618 / 1290	1.8E-3	1.7E-8	4.4E-1	6.0E-3	5.7E-8	3.8E-1
RFETS	2171877 / 2307	6.7E-5	9.0E-10	6.3E-1	2.3E-4	3.1E-9	4.1E-3
WVDP	1698391 / 10	1.7E-7	2.6E-12	3.2E-3	5.9E-7	8.9E-12	9.7E-5
KCP	1729833 / 0	2.5E-9	1.1E-13	5.9E-5	8.4E-9	3.8E-13	2.8E-6
Hanford	377645 / 2065	1.4E-3	2.8E-8	6.0E-1	4.7E-3	9.6E-8	4.2E-1
INEL	153061 / 1587	5.2E-5	6.5E-9	5.3E-1	1.8E-4	2.2E-8	3.6E-1
PGDP	500502 / 144	1.2E-4	1.3E-8	4.7E-2	4.1E-4	4.5E-8	1.4E-3
ANL-E	7939785 / 200	6.0E-6	3.3E-11	5.7E-2	2.1E-5	1.1E-10	3.6E-2
TOTAL		1.6E-1	2.6E-6	4.3	5.5E-1	8.7E-6	2.0

[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 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.
[d] Offsite.

Table D.3.5-18. Risks Associated with Treatment of LLMW Under the Regionalized Alternative 2, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 200	6.0E-6	3.3E-11	5.7E-2	2.1E-5	1.1E-10	3.6E-2
BNL	5738554 / 16	5.2E-8	7.0E-13	4.0E-3	1.9E-7	2.5E-12	2.0E-4
FEMP	2764589 / 269	1.4E-7	2.7E-12	8.8E-2	5.8E-7	1.2E-11	8.8E-4
KAPL-K	1290172 / 9	2.6E-7	5.8E-12	2.8E-3	8.9E-7	2.0E-11	2.2E-3
LBL	5856829 / 8	9.8E-9	1.5E-13	1.9E-3	4.9E-8	8.3E-13	7.4E-5
LANL	159152 / 679	8.6E-4	9.1E-8	2.2E-1	2.9E-3	3.1E-7	8.2E-3
LLNL	6324234 / 136	4.4E-7	7.2E-12	3.3E-2	1.9E-6	3.5E-11	2.2E-3
ORR	881652 / 2177	1.2E-3	3.6E-8	6.0E-1	4.1E-3	1.3E-7	4.2E-1
Mound	3032983 / 5	5.9E-9	3.4E-13	1.1E-3	7.3E-8	2.9E-12	4.3E-5
NTS	14266 / 0	7.0E-15	0.00	2.4E-5	2.5E-14	0.00	9.1E-7
Pantex	265185 / 48	2.3E-6	2.0E-10	1.5E-2	8.0E-6	6.8E-10	5.8E-4
Ports	639602 / 1951	1.1E-4	1.3E-8	5.4E-1	3.6E-4	4.5E-8	2.7E-1
SNL-NM	610714 / 5	1.8E-8	7.1E-13	1.2E-3	6.1E-8	2.4E-12	6.1E-5
SRS	620618 / 1290	1.8E-3	1.7E-8	4.4E-1	6.0E-3	5.7E-8	3.8E-1
RFETS	2171877 / 2307	6.8E-5	9.2E-10	6.3E-1	2.4E-4	3.2E-9	4.6E-3
WVDP	1698391 / 10	1.7E-7	2.6E-12	3.2E-3	5.8E-7	8.9E-12	9.7E-5
KCP	1729833 / 0	2.5E-9	1.1E-13	5.9E-5	8.4E-9	3.8E-13	2.8E-6
INEL	153061 / 2010	6.3E-4	7.8E-8	6.6E-1	2.1E-3	2.7E-7	3.9E-1
Hanford	377645 / 2132	1.3E-2	2.7E-7	6.4E-1	4.5E-2	9.2E-7	5.0E-1
PGDP	500502 / 48	8.1E-7	9.0E-11	1.3E-2	2.8E-6	3.1E-10	5.2E-4
TOTAL		1.8E-2	2.7E-7	4.0	6.1E-2	9.2E-7	2.0

[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 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.
[d] Offsite.

Table D.3.5–19. Risks Associated with Treatment of LLMW Under the Regionalized Alternative 3, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 200	6.0E-6	3.3E-11	5.7E-2	2.1E-5	1.1E-10	3.6E-2
BNL	5738554 / 16	5.2E-8	7.0E-13	4.0E-3	1.9E-7	2.5E-12	2.0E-4
FEMP	2764589 / 269	1.4E-7	2.7E-12	8.8E-2	5.8E-7	1.2E-11	8.8E-4
KAPL-K	1290172 / 9	2.6E-7	5.8E-12	2.8E-3	8.9E-7	2.0E-11	2.2E-3
LBL	5856829 / 8	9.8E-9	1.5E-13	1.9E-3	4.9E-8	8.3E-13	7.4E-5
LANL	159152 / 679	8.6E-4	9.1E-8	2.2E-1	2.9E-3	3.1E-7	8.2E-3
LLNL	6324234 / 136	4.4E-7	7.2E-12	3.3E-2	1.9E-6	3.5E-11	2.2E-3
ORR	881652 / 2177	1.2E-3	3.6E-8	6.0E-1	4.1E-3	1.3E-7	4.2E-1
Mound	3032983 / 5	5.9E-9	3.4E-13	1.1E-3	7.3E-8	2.9E-12	4.3E-5
NTS	14266 / 0	7.0E-15	0.00	2.4E-5	7.1E-8	1.8E-11	9.1E-7
Pantex	265185 / 48	2.3E-6	2.0E-10	1.5E-2	8.0E-6	6.8E-10	5.8E-4
Ports	639602 / 1951	1.1E-4	1.3E-8	5.4E-1	3.6E-4	4.5E-8	2.7E-1
SNL-NM	610714 / 5	1.8E-8	7.1E-13	1.2E-3	6.1E-8	2.4E-12	6.1E-5
SRS	620618 / 1290	1.8E-3	1.7E-8	4.4E-1	6.0E-3	5.7E-8	3.8E-1
RFETS	2171877 / 2307	6.8E-5	9.2E-10	6.3E-1	2.4E-4	3.2E-9	4.6E-3
WVDP	1698391 / 10	1.7E-7	2.6E-12	3.2E-3	5.8E-7	8.9E-12	9.7E-5
KCP	1729833 / 0	2.5E-9	1.1E-13	5.9E-5	8.4E-9	3.8E-13	2.8E-6
Hanford	377645 / 2132	1.3E-2	2.7E-7	6.4E-1	4.5E-2	9.2E-7	5.0E-1
INEL	153061 / 2010	6.3E-4	7.8E-8	6.6E-1	2.1E-3	2.7E-7	3.9E-1
PGDP	500502 / 48	8.1E-7	9.0E-11	1.3E-2	2.8E-6	3.1E-10	5.2E-4
TOTAL		1.8E-2	2.7E-7	4.0	6.1E-2	9.2E-7	2.0

[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 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.
[d] Offsite.

Table D.3.5–20. Risks Associated with Treatment of LLMW Under the Regionalized Alternative 4, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 200	6.0E-6	3.3E-11	5.7E-2	2.1E-5	1.1E-10	3.6E-2
BNL	5738554 / 16	5.2E-8	7.0E-13	4.0E-3	1.9E-7	2.5E-12	2.0E-4
FEMP	2764589 / 269	1.4E-7	2.7E-12	8.8E-2	5.8E-7	1.2E-11	8.8E-4
KAPL-K	1290172 / 9	2.6E-7	5.8E-12	2.8E-3	8.9E-7	2.0E-11	2.2E-3
LBL	5856829 / 8	9.8E-9	1.5E-13	1.9E-3	4.9E-8	8.3E-13	7.4E-5
LANL	159152 / 146	3.8E-5	4.0E-9	4.4E-2	1.3E-4	1.4E-8	2.4E-3
LLNL	6324234 / 136	4.4E-7	7.2E-12	3.3E-2	1.9E-6	3.5E-11	2.2E-3
ORR	881652 / 3116	1.6E-3	5.0E-8	9.5E-1	5.6E-3	1.7E-7	8.5E-1
Mound	3032983 / 5	6.0E-9	3.5E-13	1.2E-3	7.4E-8	2.9E-12	4.6E-5
NTS	14266 / 0	7.0E-15	0.00	2.4E-5	2.5E-14	0.00	9.1E-7
Pantex	265185 / 48	2.3E-6	2.0E-10	1.5E-2	8.0E-6	6.8E-10	5.8E-4
Ports	639602 / 405	1.8E-8	2.3E-12	1.2E-1	1.1E-7	1.6E-11	2.9E-3
SNL-NM	610714 / 5	1.8E-8	7.1E-13	1.2E-3	6.1E-8	2.4E-12	6.1E-5
SRS	620618 / 1291	1.8E-3	1.7E-8	4.4E-1	6.0E-3	5.7E-8	3.8E-1
RFETS	2171877 / 769	1.3E-6	1.8E-11	2.1E-1	4.9E-6	6.4E-11	3.5E-3
WVDP	1698391 / 11	1.7E-7	2.6E-12	3.3E-3	6.0E-7	9.1E-12	1.0E-4
KCP	1729833 / 0	2.5E-9	1.1E-13	5.9E-5	8.4E-9	3.8E-13	2.8E-6
INEL	153061 / 3281	6.7E-4	8.4E-8	1.0	2.3E-3	2.8E-7	4.2E-1
Hanford	377645 / 2268	1.3E-2	2.7E-7	6.9E-1	4.5E-2	9.3E-7	5.2E-1
PGDP	500502 / 48	8.1E-7	9.0E-11	1.3E-2	2.8E-6	3.1E-10	5.2E-4
TOTAL		1.8E-2	2.7E-7	3.7	5.9E-2	9.3E-7	2.2

[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 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.
[d] Offsite.

Table D.3.5-21. Risks Associated with Treatment of LLMW Under the Centralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 200	6.0E-6	3.3E-11	5.7E-2	2.1E-5	1.1E-10	3.6E-2
BNL	5738554 / 16	5.2E-8	7.0E-13	4.0E-3	1.9E-7	2.5E-12	2.0E-4
FEMP	2764589 / 269	1.4E-7	2.7E-12	8.8E-2	5.8E-7	1.2E-11	8.8E-4
KAPL-K	1290172 / 9	2.6E-7	5.8E-12	2.8E-3	8.9E-7	2.0E-11	2.2E-3
LBL	5856829 / 8	9.8E-9	1.5E-13	1.9E-3	4.9E-8	8.3E-13	7.4E-5
LANL	159152 / 146	3.8E-5	4.0E-9	4.4E-2	1.3E-4	1.4E-8	2.4E-3
LLNL	6324234 / 136	4.4E-7	7.2E-12	3.3E-2	1.9E-6	3.5E-11	2.2E-3
ORR	881652 / 490	6.8E-6	2.1E-10	1.6E-1	2.4E-5	7.7E-10	8.4E-2
Mound	3032983 / 5	6.0E-9	3.5E-13	1.2E-3	7.4E-8	2.9E-12	4.6E-5
NTS	14266 / 0	7.0E-15	0.00	2.4E-5	2.5E-14	0.00	9.1E-7
Pantex	265185 / 48	2.3E-6	2.0E-10	1.5E-2	8.0E-6	6.8E-10	5.8E-4
Ports	639602 / 405	1.8E-8	2.3E-12	1.2E-1	1.1E-7	1.6E-11	2.9E-3
SNL-NM	610714 / 5	1.8E-8	7.1E-13	1.2E-3	6.1E-8	2.4E-12	6.1E-5
SRS	620618 / 207	1.3E-6	1.3E-11	8.1E-2	4.6E-6	4.4E-11	1.1E-1
RFETS	2171877 / 769	1.3E-6	1.8E-11	2.1E-1	4.9E-6	6.4E-11	3.5E-3
WVDP	1698391 / 11	1.7E-7	2.6E-12	3.3E-3	5.9E-7	9.1E-12	1.0E-4
KCP	1729833 / 0	2.5E-9	1.1E-13	5.9E-5	8.4E-9	3.8E-13	2.8E-6
INEL	153061 / 278	4.9E-6	6.1E-10	1.5E-1	1.7E-5	2.1E-9	2.5E-1
Hanford	377645 / 6706	2.5E-2	5.2E-7	2.2	8.5E-2	1.8E-6	1.8
PGDP	500502 / 48	8.1E-7	9.0E-11	1.3E-2	2.8E-6	3.1E-10	5.2E-4
TOTAL		2.5E-2	5.2E-7	3.2	8.6E-2	1.8E-6	2.3

[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 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.
[d] Offsite.

Table D.3.5-22. Risks Associated with Treatment of RH-LLMW Under Each Alternative (Except No Action), by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 / 1	4.4E-7	9.1E-12	1.7E-4	1.5E-6	3.1E-11	2.4E-9
ORR	881652 / 725	1.1E-3	3.4E-8	3.0E-1	3.7E-3	1.2E-7	7.5E-2
INEL	153061 / 569	2.1E-4	2.6E-8	1.7E-1	7.0E-4	8.7E-8	6.9E-3
SRS	620618 / 17	3.0E-5	2.8E-10	5.1E-3	1.0E-4	9.6E-10	4.8E-6
TOTAL		1.3E-3	3.4E-8	4.7E-1	4.5E-3	1.2E-7	8.1E-2

[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 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.
[d] Offsite.

Table D.3.5-23. Program-Wide Risks Associated with Disposal of LLMW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	3.6			
	Cancer Fatalities	1.8E-3			
	Cancer Incidence	6.1E-3	1.1E-2		
	Genetic Effects	3.6E-4			
	Hazard Index			3.0	
All Lifetimes	Dose (person-rem)	1.0E2			
	Cancer Fatalities	5.0E-2			
	Cancer Incidence	1.7E-1	5.1E-1		
	Genetic Effects	1.0E-2			
	Hazard Index			3.0	
WM Workers	Dose (FTE-rem)	1.4E3			
	Cancer Fatalities	5.5E-1			
	Cancer Incidence	1.9			
	Genetic Effects	8.3E-2			
	Exposure Index				
	Construction Fatalities				1.3E-1
	Construction Injuries				5.9E1
	Operation Fatalities				3.4E-1
	Operation Injuries				2.9E2

Table D.3.5-24. Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	2.4			
	Cancer Fatalities	1.2E-3			
	Cancer Incidence	4.1E-3	1.0E-2		
	Genetic Effects	2.4E-4			
	Hazard Index			3.0	
All Lifetimes	Dose (person-rem)	4.7E1			
	Cancer Fatalities	2.4E-2			
	Cancer Incidence	8.0E-2	5.0E-1		
	Genetic Effects	4.7E-3			
	Hazard Index			3.0	
WM Workers	Dose (FTE-rem)	1.4E3			
	Cancer Fatalities	5.5E-1			
	Cancer Incidence	1.9			
	Genetic Effects	8.3E-2			
	Exposure Index				
	Construction Fatalities				1.2E-1
	Construction Injuries				5.4E1
	Operation Fatalities				3.3E-1
	Operation Injuries				2.8E2

Table D.3.5-25. Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	2.8			
	Cancer Fatalities	1.4E-3			
	Cancer Incidence	4.8E-3	1.3E-2		
	Genetic Effects	2.8E-4			
	Hazard Index			2.7	
All Lifetimes	Dose (person-rem)	4.7E1			
	Cancer Fatalities	2.4E-2			
	Cancer Incidence	8.0E-2	8.3E-1		
	Genetic Effects	4.7E-3			
	Hazard Index			2.7	
WM Workers	Dose (FTE-rem)	1.3E3			
	Cancer Fatalities	5.2E-1			
	Cancer Incidence	1.8			
	Genetic Effects	7.8E-2			
	Exposure Index				
	Construction Fatalities				1.1E-1
	Construction Injuries				4.7E1
	Operation Fatalities				3.1E-1
	Operation Injuries				2.6E2

Table D.3.5-26. Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	0.00			
	Cancer Fatalities	0.00			
	Cancer Incidence	0.00	2.8E-3		
	Genetic Effects	0.00			
	Hazard Index			3.1E-1	
All Lifetimes	Dose (person-rem)	0.00			
	Cancer Fatalities	0.00			
	Cancer Incidence	0.00	5.4E-2		
	Genetic Effects	0.00			
	Hazard Index			3.1E-1	
WM Workers	Dose (FTE-rem)	9.2E2			
	Cancer Fatalities	3.7E-1			
	Cancer Incidence	1.3			
	Genetic Effects	5.5E-2			
	Exposure Index				
	Construction Fatalities				5.2E-2
	Construction Injuries				2.3E1
	Operation Fatalities				1.3E-1
	Operation Injuries				1.1E2

Table D.3.5–27. Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	3.0			
	Cancer Fatalities	1.5E-3			
	Cancer Incidence	5.1E-3	1.3E-2		
	Genetic Effects	3.0E-4			
	Hazard Index			2.7	
All Lifetimes	Dose (person-rem)	5.0E1			
	Cancer Fatalities	2.5E-2			
	Cancer Incidence	8.5E-2	8.2E-1		
	Genetic Effects	5.0E-3			
	Hazard Index			2.7	
WM Workers	Dose (FTE-rem)	1.6E3			
	Cancer Fatalities	6.4E-1			
	Cancer Incidence	2.2			
	Genetic Effects	9.5E-2			
	Exposure Index				
	Construction Fatalities				1.0E-1
	Construction Injuries				4.4E1
	Operation Fatalities				3.1E-1
	Operation Injuries				2.7E2

Table D.3.5–28. Program-Wide Risks Associated with Disposal of LLMW Under the Centralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	3.9E1			
	Cancer Fatalities	1.9E-2			
	Cancer Incidence	6.6E-2	9.5E-4		
	Genetic Effects	3.9E-3			
	Hazard Index			2.4	
All Lifetimes	Dose (person-rem)	5.0E2			
	Cancer Fatalities	2.5E-1			
	Cancer Incidence	8.6E-1	8.5E-3		
	Genetic Effects	5.0E-2			
	Hazard Index			2.4	
WM Workers	Dose (FTE-rem)	9.1E2			
	Cancer Fatalities	3.6E-1			
	Cancer Incidence	1.3			
	Genetic Effects	5.4E-2			
	Exposure Index				
	Construction Fatalities				1.9E-2
	Construction Injuries				8.1
	Operation Fatalities				1.3E-1
	Operation Injuries				1.1E2

Table D.3.5–29. Program-Wide Risks Associated with Disposal of RH-LLMW Under Each Alternative (Except No Action), by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	1.7E-1			
	Cancer Fatalities	8.5E-5			
	Cancer Incidence	2.9E-4	1.4E-5		
	Genetic Effects	1.7E-5			
	Hazard Index			1.3E-2	
All Lifetimes	Dose (person-rem)	2.7			
	Cancer Fatalities	1.3E-3			
	Cancer Incidence	4.5E-3	5.8E-4		
	Genetic Effects	2.7E-4			
	Hazard Index			1.3E-2	
WM Workers	Dose (FTE-rem)	3.7			
	Cancer Fatalities	1.5E-3			
	Cancer Incidence	5.2E-3			
	Genetic Effects	2.2E-4			
	Exposure Index				
	Construction Fatalities				9.4E-3
	Construction Injuries				4.1
	Operation Fatalities				2.1E-2
	Operation Injuries				1.8E1

Table D.3.5-30. Risks Associated with Disposal of LLMW Under the Decentralized Alternative, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	9.4E-4	1.8E-2	2.8E-1	3.7E-3	6.5E-2	7.1E-1
INEL (0)	0.00	0.00	1.9E-1	3.0E-5	4.1E-5	4.9E-1
LLNL (142)	1.3E-6	2.0E-5	6.3E-2	7.8E-6	2.6E-4	1.4E-1
LANL (0)	0.00	0.00	1.3E-2	3.1E-4	5.5E-3	5.5E-3
NTS (0)	0.00	0.00	1.2E-2	2.2E-4	3.5E-3	1.9E-3
ORR (22)	3.8E-6	5.9E-5	1.3E-1	6.4E-3	4.5E-1	2.8E-1
PGDP (146)	7.8E-6	6.6E-5	3.1E-3	2.8E-5	2.4E-4	4.8E-4
Pantex (96)	2.7E-6	8.6E-5	5.1E-3	1.4E-5	3.6E-4	1.1E-3
Ports (145)	3.1E-5	1.1E-3	6.6E-2	5.4E-4	8.8E-3	1.3E-1
RFETS (38)	1.6E-6	3.1E-5	7.1E-2	1.1E-3	2.5E-2	8.2E-3
SNL-NM (92)	1.8E-4	9.3E-3	7.7E-4	6.2E-4	3.2E-2	1.2E-4
SRS (153)	9.7E-5	1.3E-3	1.4E-1	1.3E-3	7.2E-3	1.4E-1
ANL-E (64)	3.4E-4	1.5E-2	5.2E-2	2.1E-3	6.5E-2	4.3E-2
BNL (78)	4.2E-5	2.6E-3	1.6E-3	1.8E-4	9.0E-3	2.1E-4
FEMP (53)	1.5E-4	2.5E-3	9.3E-3	7.8E-6	2.6E-4	1.0E-3
TOTAL	1.8E-3	5.0E-2	1.0	1.7E-2	6.8E-1	1.9

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[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.3.5-31. Risks Associated with Disposal of LLMW Under the Regionalized Alternative 1, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
FEMP (53)	1.5E-4	2.5E-3	9.3E-3	5.7E-4	8.7E-3	1.0E-3
INEL (0)	0.00	0.00	1.9E-1	3.0E-5	4.1E-5	4.9E-1
LLNL (142)	1.3E-6	2.0E-5	6.3E-2	7.8E-6	2.6E-4	1.4E-1
LANL (0)	0.00	0.00	1.3E-2	3.1E-4	5.5E-3	6.7E-3
NTS (0)	0.00	0.00	1.4E-2	2.2E-4	3.5E-3	1.9E-3
ORR (22)	3.0E-6	4.7E-5	1.2E-1	6.4E-3	4.5E-1	2.5E-1
PGDP (146)	7.8E-6	6.6E-5	3.1E-3	2.8E-5	2.4E-4	4.8E-4
Pantex (96)	2.7E-6	8.6E-5	5.1E-3	1.4E-5	3.6E-4	1.1E-3
Ports (145)	8.5E-5	3.1E-3	1.1E-1	8.5E-4	1.7E-2	2.0E-1
RFETS (38)	1.6E-6	3.1E-5	7.1E-2	1.1E-3	2.5E-2	8.2E-3
SRS (153)	9.7E-5	1.3E-3	1.4E-1	1.3E-3	7.2E-3	1.4E-1
Hanford (18)	8.6E-4	1.7E-2	2.7E-1	3.4E-3	6.1E-2	7.0E-1
TOTAL	1.2E-3	2.4E-2	1.0	1.4E-2	5.8E-1	1.9

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[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.3.5-32. Risks Associated with Disposal of LLMW Under the Regionalized Alternative 2, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.3E-3	2.2E-2	2.9E-1	4.9E-3	8.0E-2	7.4E-1
INEL (0)	0.00	0.00	2.2E-1	3.0E-5	4.2E-5	5.8E-1
LANL (0)	0.00	0.00	1.4E-1	1.7E-4	3.2E-3	4.0E-2
NTS (0)	0.00	0.00	3.9E-4	1.4E-9	2.1E-8	2.5E-5
ORR (22)	3.6E-6	5.8E-5	1.5E-1	1.2E-2	8.1E-1	3.3E-1
SRS (153)	9.7E-5	1.3E-3	1.4E-1	1.3E-3	7.2E-3	1.4E-1
TOTAL	1.4E-3	2.4E-2	9.4E-1	1.8E-2	9.1E-1	1.8

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[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.3.5-33. Risks Associated with Disposal of LLMW Under the Regionalized Alternative 3, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	5.5E-1	2.8E-3	5.4E-2	1.3
TOTAL	0.00	0.00	5.5E-1	2.8E-3	5.4E-2	1.3

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[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.3.5-34. Risks Associated with Disposal of LLMW Under the Regionalized Alternative 4, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
INEL (0)	0.00	0.00	4.0E-1	1.7E-5	2.2E-5	1.0
LANL (0)	0.00	0.00	7.6E-2	4.7E-7	8.4E-6	5.5E-3
NTS (0)	0.00	0.00	3.3E-4	1.4E-9	2.1E-8	2.5E-5
ORR (22)	4.3E-6	7.0E-5	1.5E-1	1.2E-2	8.2E-1	3.3E-1
SRS (153)	9.7E-5	1.3E-3	1.4E-1	1.3E-3	7.2E-3	1.4E-1
Hanford (18)	1.4E-3	2.4E-2	2.9E-1	5.2E-3	8.5E-2	7.4E-1
TOTAL	1.5E-3	2.5E-2	1.1	1.8E-2	9.1E-1	2.2

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[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.3.5-35. Risks Associated with Disposal of LLMW Under the Centralized Alternative, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.9E-2	2.5E-1	5.1E-1	6.7E-2	8.7E-1	1.3
TOTAL	1.9E-2	2.5E-1	5.1E-1	6.7E-2	8.7E-1	1.3

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[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.3.5-36. Risks Associated with Disposal of RH-LLMW Under Each Alternative (Except No Action), by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
INEL (0)	0.00	0.00	2.1E-2	7.6E-7	1.2E-6	3.5E-3
Hanford (18)	2.4E-7	5.0E-6	2.5E-5	8.5E-7	1.7E-5	3.2E-11
ORR (22)	8.3E-5	1.3E-3	9.7E-3	2.9E-4	5.0E-3	1.8E-3
SRS (153)	2.1E-6	2.9E-5	1.2E-3	1.2E-5	1.1E-4	2.2E-6
TOTAL	8.5E-5	1.3E-3	3.2E-2	3.0E-4	5.1E-3	5.2E-3

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

D.3.5.4 Results of the LLMW Human Health Risk Analysis for Routine Operations

D.3.5.4.1 *Program-Wide Trends in Human Health Risks Associated with LLMW Management Alternatives*

For the offsite and noninvolved worker populations and their respective MEIs, the cancer fatality risks associated with CH-LLMW treatment Regionalized Alternatives 2, 3, 4, and the Centralized Alternative are generally lower than for No Action, Decentralized, and Regionalized 1, due to reduction in the number of treatment installations and the transfer of waste to installations where offsite populations are smaller and/or farther away from treatment facilities. However, for the offsite population and both MEIs, cancer fatality risks in the Centralized Alternative are slightly higher (less than a factor of two) than those associated with Regionalized 2, 3, and 4. In all alternatives, radiological risks to offsite and noninvolved worker receptors are higher than risks from chemical exposure.

Risk of cancer incidence to offsite and noninvolved worker populations and offsite MEIs from chemical exposure follows a similar trend, decreasing as fewer installations treat LLMW. However, for the noninvolved worker MEI, chemical-related cancer incidence risk increases slightly when all treatment is

performed at only one installation. All hazard indices are all well below 1.0, indicating a low probability of adverse health effects due to noncarcinogenic, toxic chemicals.

For workers, the No Action Alternative (which entails treatment of RH- and CH-LLMW) and all CH-LLMW treatment alternatives are very similar for all health risk endpoints. However, the cancer incidence risks due to chemical exposure are 1 to 2 orders of magnitude lower than the cancer incidence risks due to radionuclide exposure. All exposure indices are well below 1.0, indicating a low probability of adverse health effects due to noncarcinogenic, toxic chemicals.

For all receptors, cancer risks associated with RH-LLMW treatment (in all alternatives except No Action) are greater at ORR and INEL than at other installations because these two installations treat substantially larger waste loads.

Offsite Population. The No Action, 49-installation treatment, and 11-installation treatment alternatives (No Action, Decentralized, and Regionalized 1, respectively) produce risks of cancer fatality to the offsite population approximately 1 order of magnitude higher than the 7-, 4-, and 1-installation treatment alternatives (Regionalized 2, 3, 4, and Centralized). This is because CH-LLMW is being transferred for treatment from LLNL (which has a population of 6.3 million located relatively close to the facility) to Hanford (which has a population of 380,000 located farther from the facility). Total cancer fatality risks for No Action, Decentralized, and Regionalized 1 range from 1.6E-1 to 3.1E-1 over a total affected population of approximately 38.5 million; whereas the risks in Regionalized 2, 3, 4, and Centralized range from 1.8E-2 to 2.5E-2 for the same affected population.

For No Action and the alternatives involving treatment of CH-LLMW, most of the estimated cancer fatality risk can be attributed to exposure to uranium-238 at ORR (No Action), tritium at LLNL (Decentralized and Regionalized 1), and tritium at Hanford (Regionalized 2, 3, 4, and Centralized). The installations that pose the highest risk, by alternative, are ORR in No Action; LLNL in Decentralized and Regionalized 1; and Hanford in Regionalized 2, 3, 4, and Centralized. (As discussed in Chapter 6, the risk estimates in this section are based on the assumption that LLMW will be incinerated. The highest health risks to the offsite population are estimated to result from releases of tritium during incineration of wastes containing tritium. It should be noted that DOE is exploring alternative technologies for treating LLMW where incineration is determined to be unacceptable based on potential health risks.)

Cancer incidence risk to offsite populations from exposure to carcinogenic chemicals follows the trends for radiological risks, generally decreasing from No Action to Centralized. The highest chemical-related cancer incidence risk is in No Action (2.9E-3) by approximately 1 to 2 orders of magnitude over other alternatives. The lowest estimated cancer incidence due to chemical exposure is in the Centralized Alternative (1.5E-5).

The treatment of RH-LLMW at four installations presents a program-wide risk of cancer fatality to the offsite population of 1.3E-3 over a total affected population of approximately 2 million (in all alternatives except No Action). The highest installation-specific cancer fatality risk associated with RH-LLMW treatment is at ORR due to tritium emissions during management of a relatively large waste volume. The estimated program-wide risk of cancer incidence from chemical exposure is 7.2E-8 for the RH-LLMW treatment scenario.

Noninvolved Worker Population. The program-wide health risks to noninvolved worker populations parallel the trends observed for the offsite populations. Cancer fatality risks in No Action, Decentralized, and Regionalized 1 are approximately 1 to 2 orders of magnitude higher than in Regionalized 2, 3, 4, and Centralized. The risk of cancer fatality to noninvolved worker populations ranges from 3.3E-4 (Centralized) to 1.3E-2 (No Action) for CH-LLMW.

The No Action Alternative presents the highest risk of cancer fatality (1.3E-2) to the noninvolved worker population and is approximately 1 order of magnitude higher than the next-highest alternative. The 49-installation and 11-installation CH-LLMW treatment alternatives (Decentralized and Regionalized 1) produce risks of cancer fatality (2.4E-3 in each alternative) for the noninvolved worker population approximately 1 order of magnitude higher than for the 7-, 4-, and 1-installation treatment alternatives (Regionalized 2, 3, 4, and Centralized) (3.3E-4 to 3.6E-4), because at LLNL, a larger population of noninvolved workers is located closer to the facility than at Hanford. (There are 9,500 noninvolved workers located 800 m from the facility at LLNL compared to 160 people at Hanford).

The risk of cancer incidence to noninvolved worker populations from exposure to carcinogenic chemicals in CH-LLMW ranges from 7.9E-6 (Centralized) to 5.8E-4 (No Action), following the same general trend as for offsite populations.

The treatment of RH-LLMW at four installations (all alternatives except No Action) results in a risk to noninvolved worker populations of 4.2E-5 for cancer fatality and a risk of 3.9E-8 for cancer incidence due to chemical exposure.

Most-Exposed Noninvolved Workers and Most-Exposed Offsite Individuals. For CH-LLMW, the trends in cancer fatality risks to offsite MEIs are similar to those for offsite and noninvolved worker populations in that Regionalized 2, 3, 4, and Centralized generally have lower risks than No Action, Decentralized, and Regionalized 1. Risk of cancer incidence to offsite and noninvolved worker populations and offsite MEIs due to chemical exposure follows a similar trend, decreasing as fewer installations treat LLMW. However, both cancer fatality risks and chemical-related cancer incidence risks to the noninvolved worker MEI increase slightly (less than a factor of two) in the Centralized Alternative (compared to Regionalized 2, 3, and 4), reflecting increased exposure of the noninvolved worker MEI with consolidation of waste and treatment at one installation.

The No Action Alternative has the highest risk of cancer fatality for the offsite and noninvolved worker MEIs, (7.0E-6 and 8.7E-6, respectively). The risk of cancer incidence due to chemicals is about 2 or more orders of magnitude less than the risk of cancer incidence due to radionuclides for both MEIs. The hazard index for the offsite MEI ranges from 4.8E-9 to 2.3E-5, whereas the hazard index for the noninvolved worker MEI ranges from 3.8E-8 to 4.5E-5. The hazard indices for all MEIs are well below 1.0 in all alternatives, indicating a low probability of health effects from noncarcinogenic constituents.

Treatment of RH-LLMW at four installations results in cancer fatality risks to the offsite and noninvolved worker MEIs of 3.4E-8 and 2.3E-8 respectively, and risks of cancer incidence from chemical exposure of 2.9E-12 and 1.8E-11, respectively.

Workers. Total estimated risks of cancer incidence and cancer fatalities to workers due to radionuclide exposure are very similar among alternatives, differing by less than a factor of two. Estimated cancer fatalities for No Action and the CH treatment alternatives range from 5.2E-1 to 8.7E-1 out of a total population ranging from about 9,200 to 15,100 FTEs). Risk of cancer incidence due to radiation exposure ranges from 1.8 to 3.0 for the same alternatives. Risks of cancer fatalities and incidence to workers due to radionuclide exposure in the RH treatment scenario are 2.3E-2 and 8.1E-2, respectively, out of a total worker population of 1,312 FTEs.

Worker health risks due to chemical exposure are also similar among alternatives (No Action and CH-LLMW treatment). The highest cancer incidence (1.8E-2 out of a total population of 9,756 FTEs) and the highest exposure index (2.6E-2) due to chemical exposure are for the Centralized Alternative where all waste is treated at Hanford. In this alternative, chemical waste loads are substantially larger at Hanford, and more workers are processing more waste at a time to complete treatment over the 10-year period. However, chemical exposure risks associated with the Centralized Alternative are higher only by about a factor of two over other alternatives. For RH-LLMW, cancer incidence risk due to chemical exposure is 6.7E-5, and the exposure index is 4.6E-4 (in each alternative except No Action).

All worker cancer incidence risks due to chemical exposure are 1 to 2 orders of magnitude lower than cancer incidence risks due to radionuclide exposure. All exposure indices are well below 1.0.

Estimated construction fatality risks for CH treatment are also very similar among alternatives, ranging from 1.4 to 2.2 (in the Regionalized and Centralized Alternatives). Construction fatality risks are slightly lower in No Action (6.2E-1). Construction fatality risk associated with RH treatment is 2.9E-1. Risk of operational fatality ranges from 1.1 to 1.9 for No Action and CH treatment alternatives, and is 1.6E-1 for the RH treatment scenario. Estimated operational fatalities are slightly lower (by about a factor of two or less) for No Action (1.1) than for other alternatives; this is due to less worker person-hours associated with treatment in No Action. Estimated construction and operational injuries follow the same patterns as fatalities.

Although, worker risks associated with CH-LLMW treatment are very similar across alternatives, some differences in installation risks are notable. The estimated total fatalities (cancer fatalities plus construction and operational fatalities) at KCP and NTS (E-5 to E-4 range) are lower by 1 or more orders of magnitude because these installations have much smaller waste loads to treat and fewer workers than other installations (1 or less FTEs in all alternatives). The same trend is seen for total cancer incidence due to radionuclide and chemical exposure at NTS and KCP (see Table D.3.5-15).

The highest total fatality and cancer incidence (from radionuclides and chemicals) risks associated with CH treatment are at Hanford in the Centralized Alternative (2.2 and 1.8, respectively). All risks at Hanford increase about 0.5 to 1 order of magnitude in the Centralized Alternative where Hanford is the only treatment installation (compared to No Action and other CH-LLMW alternatives).

The highest total fatalities and cancer incidence risks for RH treatment are at ORR (3.0E-1 and 7.5E-2, respectively) and INEL (1.7E-1 and 6.9E-3, respectively) due to much larger RH-LLMW volumes and much larger exposed work forces (725 at ORR and 569 at INEL compared to 1 at Hanford and 17 at SRS).

D.3.5.4.2 *Program-Wide Trends in Human Health Risks Associated with LLMW Disposal*

In general, Regionalized 3 (single-installation disposal of CH-LLMW at NTS) poses the lowest total health risks to all farm family lifetimes for cancer fatalities and cancer incidence. Estimated risk of cancer incidence (from radiological and chemical exposure) associated with all other CH-LLMW disposal alternatives is higher by approximately 1 order of magnitude. The estimated risk of cancer incidence to all farm family lifetimes from radionuclides ranges from zero (Regionalized 3) to 8.6E-1 (Centralized); and the estimated cancer incidence risk from carcinogenic chemicals ranges from 8.5E-3 (Centralized) to 8.3E-1 (Regionalized 2). The hazard indices (for a member of the MEL of the farm family) range from 3.1E-1 in Regionalized 3 to 3.0 in Decentralized and Regionalized 1.

Only one scenario (all alternatives except No Action) was analyzed for RH-LLMW with four installations (Hanford, INEL, ORR, and SRS) treating and disposing of all waste onsite. The risks of cancer incidence to all farm family lifetimes from radionuclides range from zero (INEL) to 4.4E-3 (ORR). The risks of cancer incidence posed by chemicals range from 2.6E-7 (Hanford) to 5.7E-4 (ORR). The hazard indices (to a member of the MEL of the farm family) range from 7.2E-5 (Hanford) to 1.3E-2 (SRS).

Most-Exposed Lifetime of the Hypothetical Farm Family. The lowest risks of cancer incidence due to radionuclide exposure to the MEL of the farm family are for Regionalized 3 in which all LLMW is disposed of at NTS. The risk of cancer incidence is zero for the farm family of four. This lack of risk is primarily due to the greater depth of the groundwater, the small amount of rainfall, and the lack of volatile radionuclides (such as carbon-14) in the waste at NTS. This results in retarded migration of contaminants into the groundwater (slow-moving, long-lived radionuclides have not yet reached the groundwater during the 10,000-year analysis period).

The highest risks of cancer incidence due to radionuclide exposure to the MEL of the farm family are for the Centralized Alternative in which all CH-LLMW is disposed of at Hanford. The risk of cancer incidence is 6.6E-2 (average individual risk of cancer incidence is 1.7E-2) during lifetime 18 with

uranium-238 as the controlling radionuclide. The elevated risks are probably due to a higher level of contaminant migration into the groundwater.

The lowest disposal installation risks are at INEL, LANL, and NTS for Decentralized and Regionalized 1, 2, and 4 and at NTS for Regionalized 3. The estimated risk of cancer incidence due to radionuclide exposure to the MEL of the farm family for each of these alternatives is zero. This is due to the lack of volatile radionuclides in the waste at installations with a greater depth to groundwater and a small amount of rainfall.

The lowest estimated risks of cancer incidence due to chemical exposure to the MEL of the farm family are for the Centralized Alternative in which CH-LLMW is disposed of at Hanford. The program-wide risk of cancer incidence is 9.5E-4 for the MEL of the farm family (individual cancer incidence risk is 2.4E-4) during lifetime 18 where 1,2-dichloroethane is the controlling contaminant.

The highest risks of cancer incidence due to chemical exposure to the MEL of the farm family are for Decentralized (15-installation disposal), Regionalized 1 (12-installation disposal), and Regionalized 2 and 4 (both 6-installation disposal). The chemical-related cancer incidence risk for each of these alternatives is very similar, ranging from 1.0E-2 to 1.3E-2. For each of these alternatives, the risk of chemical-related cancer incidence at ORR ranges from 6.4E-3 to 1.2E-2 during lifetime 61, and the controlling contaminant is 1,2-dichloroethane. The higher risk at this installation is due to a much higher concentration of volatile, potentially carcinogenic contaminants in the groundwater.

The lowest hazard index for a member of the MEL of the farm family occurs at NTS for Regionalized 2 and 4 (6.4E-8) during lifetime 37. The controlling contaminant is methylene chloride, which accounts for more than 90% of the hazard index. The hazard index is well below 1.0, therefore, exposure to noncarcinogenic, hazardous chemicals presents very few health hazards to any of the farm family lifetimes at NTS in this alternative.

The highest hazard index occurs at ORR for Regionalized 4 (1.1) during lifetime 22. The controlling contaminant is acetone, which accounts for over 70% of the hazard index. As this hazard index is greater than 1.0, it indicates a risk of toxicity to the most-exposed farm family.

For RH-LLMW disposal, the lowest estimated risks of cancer incidence due to radionuclides is at INEL where the risk to the MEL of the farm family is zero. As observed for NTS, the low amount of rainfall, the depth to groundwater, and a lack of volatile radionuclides in the waste lead to a greatly reduced risk due to retarded migration of contaminants. Estimated risk of radionuclide-related cancer incidence to the MEL of the farm family is highest at ORR with a risk of 2.8E-4 (individual cancer risk of 7.0E-5) during lifetime 22, and the driving radionuclide is neptunium-237.

The lowest risks of cancer incidence posed by chemicals in RH-LLMW is at Hanford (2.6E-8) where carbon tetrachloride is the controlling contaminant during lifetime 34. The highest estimated risk of cancer incidence due to chemicals is at SRS (4.7E-6) during lifetime 5; carbon tetrachloride is the controlling contaminant. All hazard indices are below 1.0, indicating that adverse health effects associated with noncarcinogenic chemicals are estimated to be unlikely for RH-LLMW disposal.

Workers Placing Wastes into Disposal. The estimated worker cancer fatality and incidence risks due to radionuclide exposure during disposal are very similar among alternatives, ranging from 3.6E-1 to 6.4E-1 and from 1.3 and 2.2, respectively, for the CH-LLMW treatment alternatives. However, the estimated risk of fatality from construction is lower for the one-installation disposal alternatives (Regionalized 3 and Centralized) than for other alternatives. Hanford and NTS are the single disposal installations in these alternatives and both have a large amount of existing disposal capacity compared to other installations; therefore, these two installations would require less construction of disposal facilities. The construction risks for the other CH-LLMW alternatives (Decentralized and Regionalized 1, 2, 4) are very similar. Construction fatality risk for the RH-LLMW disposal scenario is 3.0E-2. Trends in risk of construction injury follow those seen for risk of construction fatality.

The estimated number of operational fatalities is within an order of magnitude among the CH disposal alternatives (ranging from 3.4E-1 to 1.3E-1). The RH disposal scenario has an estimated operational fatality risk of 2.1E-2. In general, operational fatalities are slightly higher for alternatives where multiple installations dispose (Decentralized and Regionalized 1, 2, 4) and are slightly lower where only one installation disposes (Regionalized 3 and Centralized). This trend is due to fewer total worker person-hours associated with fewer disposal installations. Risk of operational injury to workers follows the same trend as operational fatalities.

Though overall risks to workers from disposal do not differ appreciably among CH treatment alternatives, some trends are apparent among installation risks associated with disposal. In the multiple-installation disposal alternatives (Decentralized and Regionalized 1, 2, 4), the same two installations, Hanford and INEL, have the highest cancer risks by about 0.5 to 2 orders of magnitude. These installations are consolidation installations for disposal of CH-LLMW in these alternatives. The controlling contaminants are cesium-137 at Hanford for Decentralized and cobalt-60 at Hanford and INEL for Regionalized 1, 2, and 4; external radiation is the predominant exposure route. In the one-installation disposal alternatives, the controlling contaminant at Hanford in Centralized and NTS in Regionalized 3 is cobalt-60; the primary exposure route is external radiation. Risks increase approximately 3 to 5 orders of magnitude at NTS where it is the only installation disposing in Regionalized 3; and risks go up only slightly at Hanford when it is the only disposal installation in the Centralized Alternative.

For RH-LLMW disposal, estimated risk of cancer fatality and cancer incidence from radionuclide exposure are 1.5E-3 and 5.2E-3, respectively. INEL and ORR have the greatest estimated risks to workers by 2 to 7 orders of magnitude with total estimated fatalities (exposure plus physical hazards) of 2.1E-2 and 9.7E-3 and cancer incidence (from radionuclides and chemicals) of 3.5E-3 and 1.8E-3, respectively, over Hanford and SRS. This difference in risk is attributed to the large amounts of remote-handled LLMW at INEL and ORR versus the comparatively small amounts at Hanford and SRS. The controlling radionuclide at INEL and ORR is cobalt-60 and external radiation is the primary exposure route.

D.3.5.4.3 *Comparison Among Treatment Options*

A comparison of CH-LLMW treatment options (No Action and 49-, 11-, 7-, 4-, and 1-installation treatment options) indicates that treatment risks (radiological and chemical) to offsite and noninvolved worker populations generally decrease as the number of treatment installations are reduced. This trend is due in part to transfer of waste to installations where offsite populations are smaller and/or farther away from treatment facilities. Worker risks associated with treatment are very similar for all alternatives. Radiological risks associated with treatment are consistently higher than chemical exposure risks associated with treatment for all receptors.

D.3.5.4.4 *Comparison Among Disposal Scenarios*

Direct comparisons can be made between the two CH-LLMW alternatives that involve disposal at a single installation. Regionalized 3 involves disposal at NTS, and Centralized involves disposal at Hanford. The estimated risk of cancer incidence due to radionuclide exposure is higher for Hanford (6.6E-2) than for NTS (zero). The risk of cancer incidence due to exposure to carcinogenic chemicals is slightly higher at NTS than at Hanford (2.8E-3 versus 9.5E-4, respectively). However, the hazard index at Hanford is higher by approximately one order of magnitude (3.1E-1 at NTS versus 2.4 at Hanford). Though both NTS and Hanford are in arid environments, the level of the groundwater at NTS is much deeper than at Hanford, and radionuclide contaminants migrate at a much slower rate.

Comparisons can also be made between Regionalized 2 (treat CH-LLMW at seven installations, dispose at six installations) and Regionalized 4 (treat CH-LLMW at four installations, dispose at six installations). There is no appreciable difference in the estimated risk of cancer incidence due to chemicals (4.2) or in the hazard indices (2.7). The risks of cancer incidence due to radionuclides show also little variation (8.0E-2 for Regionalized 2 and 8.5E-2 for Regionalized 4).

All worker risks associated with CH-LLMW disposal are similar among alternatives.

D.3.5.4.5 *Summary of Results for Routine Treatment and Disposal of LLMW*

In summary, the No Action Alternative presents the highest treatment health risks to the offsite and noninvolved worker populations. For treatment, radiological risks are consistently higher than chemical exposure risks for all receptors.

Since the types of treatment do not change for any of the LLMW alternatives, treatment is not a consideration for LLMW disposal. The risks are largely affected by the amount and type of waste load as well as the groundwater characteristics of the disposal installation. Geographical location of the disposal installation and the characteristics of the soil affecting the migration of contaminants into the groundwater affect the risks as well.

Worker risks are very similar across all CH-LLMW alternatives, regardless of number of treatment installations or disposal scenario. However, as might be expected, consolidation of CH-LLMW at fewer installations for treatment or disposal tends to elevate worker risks at those installations.

D.3.5.5 Summary of Alternatives for Potential LLMW Accidents

The following LLMW alternatives were evaluated for potential treatment facility (incinerator) accidents: No Action, Decentralized, Regionalized 1, Regionalized 2, Regionalized 4, and Centralized. Health risks associated with accidental releases of radionuclides and those associated with accidental releases of chemicals were analyzed separately from one another and are discussed separately in this section. In addition, the risks from accidents affecting facilities that manage alpha-emitting radionuclides were analyzed separately from the accident risks for facilities that manage non-alpha-emitting radionuclides (these two categories of radionuclides are referred to as "alpha" and "non-alpha" in the analysis). Note that incineration accident scenarios postulated for Regionalized 1 only include installations with alpha facilities.

The treatment facility accidents analyzed include (1) an incinerator explosion and resulting fire; (2) a feedstock staging area fire; and (3) an earthquake followed by an incinerator facility fire. For accidents involving chemical releases during incineration, only the feedstock staging area fire scenario is evaluated.

D.3.5.6 Special Assumptions and Considerations Used in the LLMW 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 1 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 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 and contaminant type.

For radionuclide-related accidents, the incinerator explosion is considered to be "anticipated" (greater than 1E-2); the feedstock staging area fire is considered "unlikely" (1E-4 to 1E-2); and the earthquake resulting in an incinerator facility fire is considered "very unlikely" (1E-6 to 1E-4). For chemical-related accidents, the incinerator feedstock staging area fire is considered "anticipated" (greater than 1E-2) (see Appendix W).

All "chromium" listed in the source term was assumed to be 100% chromium (VI) due to lack of more specific information. This is a conservative assumption, and health risks associated with chromium (VI) may be overestimated.

D.3.5.7 Results Tables for the Risk Analysis of Potential LLMW Accidents

Because of the volume of results tables for potential LLMW accidents, the following results tables are presented at the end of Section D.3.5.8:

- Tables D.3.5-37 and D.3.5-38 present the worst-case radionuclide- and chemical-related accidents for the offsite and noninvolved worker populations, their respective MEIs, and waste management workers for treatment facility accidents, by installation and alternative.
- Tables D.3.5-39 through D.3.5-70 present the radionuclide-related risks associated with LLMW treatment for the offsite population, offsite MEI, and worker population by alternative, installation, and accident type.

- Tables D.3.5-71 through D.3.5-113 present the chemical-related risks associated with LLMW treatment for the offsite population, offsite MEI, and worker population by alternative, installation, and accident type.

While the risk analysis results for the noninvolved worker population and noninvolved worker MEI are discussed below, the risk results for these receptors are not included in Tables D.3.5-39 through D.3.5-113. The results for the noninvolved worker receptors can be found in the supplementary risk analysis results technical document (ORNL, 1995e).

D.3.5.8 Summary of the LLMW Accident Analysis Results

Accidents Involving Releases of Radiological Contaminants. For radionuclide-related incineration accidents in all alternatives, the dominant accident type for all receptors is the earthquake resulting in a fire. The highest installation-specific cancer fatality risks are consistently associated with Hanford and/or ORR for all receptors. Cancer fatality risks associated with incineration accidents in alpha facilities are usually higher than those associated with similar accidents in non-alpha facilities by 2 times to 3 orders of magnitude (for all receptors at INEL, LANL, and RFETS in Decentralized, Regionalized 2, and Regionalized 4). However, at SRS (in all alternatives where SRS is evaluated) and at Hanford (in the Centralized Alternative), alpha facility accident risks are lower than those from similar accidents in non-alpha facilities by 1 to 2 orders of magnitude.

Accidents Involving Releases of Chemical Contaminants. For chemical-related incineration accidents in all alternatives except Centralized (where Hanford treats all LLMW), ORR is consistently the highest-risk installation for all receptors. In the Centralized Alternative, however, Hanford has the highest worker cancer incidence risk and IDLH index of all alternatives due to a greater number of exposed workers. At installations where both alpha and non-alpha LLMW are incinerated, the accident risks vary depending on contaminant inventories. At a given installation, the estimated cancer incidence risks and hazard/IDLH indices for accidents occurring in alpha incineration facilities are usually higher (in some instances by more than 2 orders of magnitude) than those estimated for similar non-alpha facility accidents. The exceptions to this are: SRS (Decentralized and Regionalized 1, 2, and 4) and Hanford (Centralized) where the risks from non-alpha incineration accidents are approximately 1 order of magnitude higher than those from alpha facility accidents; and LLNL (Decentralized and Regionalized 1) where non-alpha

incineration accident risks are only slightly higher (less than a factor of two) than similar alpha facility accident risks.

D.3.5.8.1 *Risks to the Offsite Population from LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. For incineration accidents involving releases of radionuclides from non-alpha facilities, cancer fatality risks to the offsite population range from 9.5E-9 to 4.0E-1 in population sizes ranging from 153,061 to 10,453,402. Cancer fatality risks from alpha facility incinerator accidents range from 5.4E-7 to 1.1E-2 in population sizes ranging from 153,061 to 6,324,234. 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 resulting in a fire. In each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and aircraft impact) 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-6 to 1E-4) for all installations and alternatives, while the feedstock staging area fire and incinerator explosion are considered "unlikely" (1E-4 to 1E-2) and "anticipated" (greater than 1E-2), respectively.

Hanford has the highest cancer fatality risks to the offsite population from incineration accidents in all alternatives (where Hanford is evaluated) because of relatively high releases of plutonium-238 and/or uranium-238. The highest cancer fatality risk at Hanford is 4.0E-1 (distributed over a population of 377,645) for the non-alpha earthquake scenario in the Centralized Alternative. ORR has the next highest cancer fatality risks to the offsite population from non-alpha incineration accidents. The controlling contaminant at ORR is uranium-238. Internal exposure is the primary route for both installations. The highest alpha facility accident risks are at LLNL in Decentralized and Regionalized 1 and at RFETS in Decentralized and Regionalized 1 and 2. The controlling contaminant at both installations is plutonium-238; the primary exposure route is internal.

Accidents Involving Releases of Chemical Contaminants. For incineration accidents that involve chemical releases from non-alpha facilities (feedstock staging area fire), the estimated risks of cancer incidence range from 2.1E-7 to 1.1E-2 in population sizes ranging from 153,061 to 10,453,402. Estimated risks of cancer incidence from alpha incinerator facility feedstock staging area fire accidents range from 1.5E-6 to 4.7E-4 in population sizes ranging from 153,061 to 6,324,234. All chemical-related feedstock staging area fire scenarios are considered "anticipated" (estimated annual frequency greater than 1E-2).

The highest estimated risk of cancer incidence from an accidental chemical release associated with incineration at an installation is at ORR in Regionalized 4 (1.1E-2 in a population of 881,652). In all alternatives except Centralized (in which all treatment is performed at Hanford), ORR poses the greatest risks of cancer incidence from incineration accidents, ranging from 7.3E-3 to 1.1E-2 in a population of 881,652. This is approximately 1 to 5 orders of magnitude higher than the risks at all other installations. The higher estimated cancer risk at ORR is due to a relatively large release of chromium (VI) during an incinerator accident. The alpha incineration accident with the highest risk of cancer incidence to the offsite population is the feedstock staging area fire at RFETS; the risk of cancer incidence is 4.7E-4 in a population of 2,171,877 for Decentralized and Regionalized 1 and 2. The controlling contaminant at RFETS is also chromium (VI).

Worst-case incineration accident risks do not differ much among alternatives at most installations (remain approximately equal or increase slightly with greater waste consolidation). However, cancer incidence risk to the offsite population from the worst-case accident in Decentralized and Regionalized 1, 2, and 4 is higher than for No Action at INEL by 1 to 2 orders of magnitude. In addition, cancer incidence risk from the worst-case accident at Hanford in the Centralized Alternative is higher than for Hanford in other alternatives by an order of magnitude or more due to centralized consolidation of waste loads.

D.3.5.8.2 *Risks to the Noninvolved Worker Population from LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. 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 from non-alpha facilities, cancer fatality risks range from 3.5E-10 to 1.2E-1 in population sizes ranging from 128 to 15,996. Cancer fatality risks from

alpha facility incinerator accidents range from 1.1E-7 to 2.0E-3 in population sizes ranging from 6,993 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 resulting in a fire. For each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and aircraft impact) are approximately 1 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 non-alpha facility earthquake scenario, ORR produces the greatest risk of cancer fatalities, with worst-case accident risks ranging from 8.3E-2 to 1.2E-1 in Decentralized and Regionalized 2 and 4, distributed over a population of 3,809. The next highest non-alpha accident risks are at Hanford in all alternatives (where Hanford is evaluated), with cancer fatality risks ranging from 2.2E-2 to 3.8E-2 in a population of 8,674. The controlling contaminants at ORR and Hanford are uranium-238 and plutonium-238, respectively. For alpha facility incinerator accidents, the highest-risk installations are INEL and RFETS in Decentralized and Regionalized 1 and 2 and INEL in Regionalized 4. In these alternatives, cancer fatality risk associated with the worst-case incinerator accident (earthquake) is 2.0E-3 for INEL in a population of 8,451 and 1.0E-3 for RFETS in a population of 6,993; the controlling contaminant is plutonium-238 at both installations.

Accidents Involving Releases of Chemical Contaminants. For chemical-related incineration accidents occurring in non-alpha facilities, the estimated risks of cancer incidence range from 5.1E-10 to 9.7E-4 in population sizes ranging from 128 to 15,996. Estimated risks of cancer incidence from alpha facility incinerator accidents range from 4.3E-6 to 1.7E-4 in population sizes ranging from 6,993 to 15,996. The incinerator accident resulting in the highest estimated risk of cancer incidence is the non-alpha feedstock staging area fire at ORR in Regionalized 4 (9.7E-4 in a population of 3,809). In all alternatives except Centralized (all installations treat at Hanford), ORR poses the greatest risks of cancer incidence. Incineration accident risks to noninvolved worker populations at other installations are 1 to 6 orders of magnitude lower. The controlling contaminant at ORR is chromium (VI). The alpha incineration accident with the highest risk of cancer incidence to the noninvolved worker population is the feedstock staging

area fire at INEL in Regionalized 4 (1.7E-4 in a population of 8,451). The controlling contaminant at INEL is also chromium (VI).

Worst-case accident risks of cancer incidence do not differ much among alternatives at most installations (remain approximately equal or increase slightly with greater waste consolidation). However, cancer incidence risk to the noninvolved worker population from the worst-case accident in Decentralized and Regionalized 1, 2, and 4 is higher than for No Action at INEL by 1 to 2 orders of magnitude. In addition, cancer incidence risk from the worst-case accident at Hanford in the Centralized Alternative is higher than for Hanford in other alternatives by about an order of magnitude due to centralized consolidation of waste loads.

D.3.5.8.3 *Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual from LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. 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 non-alpha facility accidents and alpha facility accidents parallel those estimated for the offsite and noninvolved worker populations.

The highest-risk incineration accident type for both MEIs is the earthquake resulting in a fire. 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 non-alpha facility earthquake scenario at ORR in No Action, Decentralized, and Regionalized 2 and 4 (ranging from 1.4E-5 to 1.6E-5). The controlling contaminant at ORR is uranium-238; the primary exposure route is internal. The next highest installation risks are for the non-alpha facility earthquake scenarios at Hanford in Centralized (9.4E-6) and PGDP in Decentralized (9.0E-6). The controlling contaminants at Hanford and PGDP are plutonium-238 and uranium-238, respectively; exposure is primarily internal.

The highest cancer fatality risk to the noninvolved worker MEI from an earthquake scenario is at Hanford (for non-alpha facilities) in Decentralized, Regionalized 2 and 4, and Centralized (ranging from 2.2E-4 to 3.9E-4). The contaminant contributing the most to risk at Hanford is plutonium-238 by internal exposure. The next highest risk to the noninvolved worker MEI is from the non-alpha earthquake scenario at ORR in Regionalized 2 and 4 (1.4E-4 and 1.1E-4 cancer fatalities, respectively). The controlling contaminant at ORR is uranium-238; exposure is primarily internal.

Accidents Involving Releases of Chemical Contaminants. For chemical-related accidents, the trends in risks to the offsite MEI and the noninvolved worker MEI tend to generally follow those for their respective populations. As observed for the offsite and noninvolved worker populations, risks and hazard indices do not differ greatly among alternatives at an installation with the exception of INEL (lower in No Action than other alternatives by about 2 orders of magnitude) and Hanford (greater in the Centralized Alternative with centralized consolidation by an order of magnitude or more).

For incineration accidents (i.e., feedstock staging area fire), the highest risks of cancer incidence to the offsite MEI (7.3E-7) and the noninvolved worker MEI (7.7E-7) occur at ORR in Regionalized 4. The cancer incidence risks to both MEIs are higher at ORR than those at other installations by 2 times to 4 orders of magnitude. The controlling carcinogenic contaminant at ORR is chromium (VI).

The highest hazard indices associated with incineration accidents are also at ORR in all alternatives (ranging from 7.8 to 9.4 for the offsite MEI and from 8.1 to 1.3E1 for the noninvolved worker MEI). For both MEIs, the hazard index is greater than 1.0 at Ports in Decentralized and Regionalized 1 and 2 (ranging from 1.3 to 1.5 for the offsite MEI and from 2.1 to 2.4 for the noninvolved worker MEI). In addition, for the noninvolved worker MEI, hazard indices are greater than 1.0 at SRS in all alternatives where SRS treats LLMW (ranging from 4.4 to 4.7) and at INEL in Regionalized 2 and 4 (ranging from 1.1 to 1.6). The controlling noncarcinogenic chemical is hydrogen chloride at ORR, Ports, SRS, and INEL. All other hazard indices are below 1.0, indicating less likelihood of harmful effects from exposure to noncarcinogens.

D.3.5.8.4 *Risks to Waste Management Workers from LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. For incineration accidents involving releases of radionuclides, installation-specific worker risks are similar among alternatives, increasing only very slightly at installations where LLMW is consolidated for treatment, most notably in the Centralized Alternative, in which estimated cancer fatalities at Hanford from all incineration accidents increase approximately half an order of magnitude. Estimated worker cancer fatalities associated with accident scenarios in non-alpha facilities range from 7.9E-8 to 1.6E-2. For alpha facility accident scenarios, estimated worker cancer fatalities range from 1.3E-4 to 3.5E-3. Shift size varies from 1 to 14 workers. In all alternatives, the earthquake and incinerator explosion scenarios produce the higher worker risks by about 1 to 2 orders of magnitude over the feedstock staging area fire scenario.

The highest installation-specific cancer fatality risks associated with non-alpha incinerator accidents are for the earthquake scenarios at ORR in No Action (9.8E-3), at ORR and Hanford in Decentralized (1.1E-2 at both installations), at ORR and Hanford in Regionalized 2 (1.6E-2 and 1.1E-2, respectively), at ORR and Hanford in Regionalized 4 (1.4E-2 and 1.1E-2, respectively), and at Hanford in the Centralized Alternative (4.4E-2). The controlling contaminants are uranium-238 at ORR and plutonium-238 at Hanford; the primary exposure route is inhalation. For alpha incinerator accidents, the highest installation cancer fatality risks are for the earthquake scenario at INEL in Decentralized and Regionalized 1, 2, and 4 (ranging from 3.1E-3 to 3.5E-3). The controlling contaminant at this installation is plutonium-238, and the primary exposure route is inhalation. Recall that the radionuclide-related earthquake scenario affecting the incinerator is considered to be "very unlikely".

Accidents Involving Releases of Chemical Contaminants. Estimated risks of cancer incidence to workers from non-alpha incineration accidents (feedstock staging area fires) range from 2.7E-12 to 7.5E-4 across alternatives. Alpha facility accident risks range from 3.2E-6 to 5.7E-5. Worker population size (shift size) varies from 1 to 14 workers. Chemical emissions from an incinerator feedstock staging area fire in a non-alpha facility are assumed to be identical regardless of installation or alternative; the same assumption was made for alpha facility accidents. Because of this, cancer incidence risk estimates for workers only vary by facility type and in direct proportion to the number of workers assumed to be present during the accident at each installation (which depends on the waste volume being incinerated at each installation).

The highest cancer incidence risk to workers from a non-alpha incinerator feedstock staging area fire is at Hanford in the Centralized Alternative (7.5E-4) due to the consolidated waste load and a greater number of workers necessary to operate the incinerator. The next highest cancer incidence risks to workers from non-alpha feedstock staging area fires are at ORR in all alternatives where ORR treats LLMW (ranging from 1.9E-4 to 3.6E-4). The highest alpha facility risks are also associated with Hanford in the Centralized Alternative (5.7E-5). The IDLH index is equal to or greater than 1.0 for all installations and alternatives, indicating a danger of irreversible health effects due to exposure to toxic chemicals. The controlling contaminants are the same at each installation, chromium (VI) and carbon monoxide.

As observed for the offsite and noninvolved worker populations and their respective MEIs, risks and IDLH indices do not differ greatly among alternatives at an installation with the exception of INEL (lower in No Action than other alternatives by about 2 orders of magnitude) and Hanford (greater in the Centralized Alternative with waste consolidation by an order of magnitude or more).

Table D.3.5–37. Radionuclide-Related Risks from Potential Worst-Case LLMW Treatment Facility Accidents, by Alternative and Installation

Installation	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
No Action										
INEL	1.3E-3	4.4E-3	1.5E-7	5.0E-7	7.2E-4	2.4E-3	4.3E-7	1.5E-6	1.4E-4	5.0E-4
ORR	1.6E-1	5.5E-1	1.4E-5	4.7E-5	8.3E-2	2.8E-1	9.2E-5	3.1E-4	9.8E-3	3.4E-2
SRS	2.0E-2	6.7E-2	6.1E-7	2.1E-6	2.2E-3	7.3E-3	9.4E-6	3.2E-5	3.2E-3	1.1E-2
Decentralized										
ANL-E	6.1E-2	2.1E-1	1.8E-6	6.2E-6	7.9E-4	2.7E-3	5.9E-6	2.0E-5	8.8E-4	3.1E-3
BNL	1.0E-2	3.5E-2	9.2E-7	3.1E-6	8.1E-5	2.8E-4	7.5E-7	2.5E-6	9.3E-6	3.2E-5
FEMP	1.6E-5	5.4E-5	4.1E-9	1.4E-8	5.9E-7	2.0E-6	4.0E-9	1.3E-8	7.0E-8	2.5E-7
Hanford	2.7E-1	9.1E-1	6.3E-6	2.1E-5	2.2E-2	7.5E-2	2.2E-4	7.6E-4	1.1E-2	3.8E-2
INEL	2.1E-3	7.1E-3	2.4E-7	8.1E-7	2.0E-3	6.8E-3	1.2E-6	4.1E-6	3.1E-3	1.1E-2
KAPL-K	4.1E-3	1.4E-2	2.1E-7	7.0E-7	6.9E-5	2.4E-4	2.8E-7	9.5E-7	5.7E-6	2.0E-5
LANL	9.1E-4	3.1E-3	4.3E-7	1.5E-6	2.6E-4	8.8E-4	7.7E-7	2.6E-6	1.7E-4	6.0E-4
LLNL	1.1E-2	3.8E-2	1.6E-6	5.3E-6	9.5E-4	3.2E-3	1.7E-6	5.6E-6	1.3E-4	4.7E-4
ORR	1.6E-1	5.5E-1	1.4E-5	4.7E-5	8.3E-2	2.8E-1	9.2E-5	3.1E-4	1.1E-2	3.9E-2
PGDP	3.1E-2	1.1E-1	9.0E-6	3.1E-5	6.1E-3	2.1E-2	5.4E-5	1.8E-4	2.3E-3	8.2E-3
Pantex	5.1E-4	1.7E-3	5.6E-8	1.9E-7	1.1E-5	3.7E-5	1.9E-7	6.4E-7	5.2E-6	1.8E-5
RFETS	5.9E-3	2.0E-2	2.1E-7	7.1E-7	1.0E-3	3.5E-3	3.1E-6	1.0E-5	3.9E-4	1.4E-3
SRS	2.0E-2	6.7E-2	6.1E-7	2.1E-6	2.2E-3	7.3E-3	9.4E-6	3.2E-5	3.2E-3	1.1E-2
Regionalized 1										
INEL	2.1E-3	7.1E-3	2.4E-7	8.1E-7	2.0E-3	6.8E-3	1.2E-6	4.1E-6	3.1E-3	1.1E-2
LANL	9.1E-4	3.1E-3	4.3E-7	1.5E-6	2.6E-4	8.8E-4	7.7E-7	2.6E-6	1.7E-4	6.0E-4
LLNL	1.1E-2	3.8E-2	1.6E-6	5.3E-6	9.5E-4	3.2E-3	1.7E-6	5.6E-6	1.3E-4	4.7E-4
RFETS	5.9E-3	2.0E-2	2.1E-7	7.1E-7	1.0E-3	3.5E-3	3.1E-6	1.0E-5	3.9E-4	1.4E-3
SRS	1.7E-3	5.9E-3	5.3E-8	1.8E-7	1.9E-4	6.5E-4	8.2E-7	2.8E-6	1.4E-4	4.9E-4
Regionalized 2										
Hanford	2.7E-1	9.1E-1	6.3E-6	2.1E-5	2.2E-2	7.5E-2	2.2E-4	7.6E-4	1.1E-2	3.8E-2
INEL	2.1E-3	7.1E-3	2.4E-7	8.1E-7	2.0E-3	6.9E-3	1.2E-6	4.1E-6	3.1E-3	1.1E-2
LANL	9.1E-4	3.1E-3	4.3E-7	1.5E-6	2.6E-4	8.8E-4	7.7E-7	2.6E-6	1.7E-4	6.0E-4
ORR	1.8E-1	6.1E-1	1.5E-5	5.1E-5	1.2E-1	4.2E-1	1.4E-4	4.6E-4	1.6E-2	5.7E-2
RFETS	5.9E-3	2.0E-2	2.1E-7	7.1E-7	1.0E-3	3.5E-3	3.1E-6	1.0E-5	3.9E-4	1.4E-3
SRS	2.0E-2	6.7E-2	6.1E-7	2.1E-6	2.2E-3	7.4E-3	9.4E-6	3.2E-5	3.2E-3	1.1E-2

Table D.3.5–37. Radionuclide-Related Risks from Potential Worst-Case LLMW Treatment Facility Accidents, by Alternative and Installation—Continued

Installation	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 4										
Hanford	2.7E-1	9.1E-1	6.3E-6	2.1E-5	2.2E-2	7.5E-2	2.2E-4	7.6E-4	1.1E-2	3.8E-2
INEL	2.1E-3	7.1E-3	2.4E-7	8.1E-7	2.0E-3	6.9E-3	1.2E-6	4.1E-6	3.5E-3	1.2E-2
ORR	1.8E-1	6.2E-1	1.6E-5	5.3E-5	9.6E-2	3.3E-1	1.1E-4	3.6E-4	1.4E-2	5.0E-2
SRS	2.0E-2	6.7E-2	6.1E-7	2.1E-6	2.2E-3	7.4E-3	9.4E-6	3.2E-5	3.2E-3	1.1E-2
Centralized										
Hanford	4.0E-1	1.4	9.4E-6	3.2E-5	3.8E-2	1.3E-1	3.9E-4	1.3E-3	4.4E-2	1.6E-1

[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.3.5-38. Chemical-Related Risks from Potential Worst-Case LLMW Treatment Facility Accidents, by Alternative and Installation

Installation	Offsite Population	Offsite MEI		Noninvolved Worker Population	Noninvolved Worker MEI[a]		Workers	
	CI[b]	CI	HI[c]	CI	CI	HI	CI	IDLH[d]
No Action								
INEL	8.9E-7	2.1E-10	3.5E-3	2.0E-6	1.2E-9	1.9E-2	7.5E-8	1.1
ORR	7.3E-3	4.7E-7	7.8	6.3E-4	5.0E-7	8.1	1.9E-4	3.0E1
SRS	1.5E-5	4.9E-9	8.1E-2	6.9E-5	2.7E-7	4.4	6.0E-5	1.4E1
Decentralized								
ANL-E	9.3E-6	2.6E-10	4.2E-3	1.4E-7	7.6E-10	1.3E-2	3.3E-7	1.1
BNL	3.2E-5	5.8E-10	9.5E-3	2.4E-8	1.9E-10	3.1E-3	1.8E-8	1.0
FEMP	2.3E-4	1.0E-8	1.6E-1	1.5E-6	9.6E-9	1.6E-1	2.1E-6	1.9
Hanford	6.5E-5	1.7E-9	2.8E-2	3.4E-7	9.1E-9	1.5E-1	2.1E-5	5.3
INEL	3.5E-5	8.2E-9	1.3E-1	7.9E-5	4.5E-8	7.4E-1	1.9E-5	4.7
KCP	2.7E-7	1.2E-11	2.0E-4	3.4E-9	1.2E-11	2.0E-4	7.7E-12	1.0
KAPL-K	3.6E-6	6.1E-10	1.0E-2	1.5E-7	6.1E-10	1.0E-2	9.3E-9	1.0
LANL	2.2E-5	7.5E-9	1.2E-1	4.3E-6	5.8E-8	9.4E-1	4.5E-6	2.6
LBL	5.6E-6	5.1E-10	8.4E-3	1.4E-7	5.3E-10	8.7E-3	3.9E-9	1.0
LLNL	8.8E-5	2.4E-8	4.0E-1	2.0E-5	3.4E-8	5.6E-1	6.0E-6	3.2
ORR	8.7E-3	5.6E-7	9.2	7.5E-4	5.9E-7	9.6	2.5E-4	3.6E1
PGDP	1.3E-4	1.9E-8	3.2E-1	1.4E-6	1.2E-8	1.9E-1	9.9E-7	1.8
Pantex	6.5E-6	4.5E-10	7.4E-3	7.8E-7	8.6E-9	1.4E-1	7.0E-7	1.9
Ports	1.1E-4	7.9E-8	1.3	4.6E-5	1.3E-7	2.1	3.4E-5	9.5
RFETS	4.7E-4	9.5E-9	1.6E-1	4.6E-6	1.2E-8	1.9E-1	4.5E-6	1.8
SNL-NM	3.5E-6	1.0E-9	1.7E-2	3.6E-7	1.0E-9	1.7E-2	4.6E-8	1.1
SRS	1.6E-5	5.2E-9	8.5E-2	7.3E-5	2.8E-7	4.7	5.9E-5	1.4E1
Regionalized 1								
FEMP	2.5E-4	1.1E-8	1.8E-1	1.6E-6	1.1E-8	1.7E-1	3.8E-6	2.0
Hanford	6.6E-5	1.7E-9	2.8E-2	3.5E-7	9.3E-9	1.5E-1	2.2E-5	5.4
INEL	3.5E-5	8.2E-9	1.3E-1	7.9E-5	4.5E-8	7.4E-1	1.9E-5	4.7
LANL	2.2E-5	7.5E-9	1.2E-1	4.3E-6	5.8E-8	9.4E-1	4.5E-6	2.6
LLNL	9.1E-5	2.5E-8	4.1E-1	2.1E-5	3.6E-8	5.8E-1	6.4E-6	3.3
ORR	8.7E-3	5.6E-7	9.2	7.6E-4	5.9E-7	9.6	2.5E-4	3.6E1
PGDP	1.3E-4	1.9E-8	3.2E-1	1.4E-6	1.2E-8	1.9E-1	9.9E-7	1.8
Pantex	6.5E-6	4.5E-10	7.4E-3	7.8E-7	8.6E-9	1.4E-1	7.0E-7	1.9
Ports	1.1E-4	8.1E-8	1.3	4.7E-5	1.3E-7	2.2	3.5E-5	9.8
RFETS	4.7E-4	9.5E-9	1.6E-1	4.6E-6	1.2E-8	1.9E-1	4.5E-6	1.8
SRS	1.6E-5	5.2E-9	8.6E-2	7.3E-5	2.9E-7	4.7	5.9E-5	1.4E1

Table D.3.5-38. Chemical-Related Risks from Potential Worst-Case LLMW Treatment Facility Accidents, by Alternative and Installation—Continued

Installation	Offsite Population	Offsite MEI		Noninvolved Worker Population	Noninvolved Worker MEI[a]		Workers	
	CI[b]	CI	HI[c]	CI	CI	HI	CI	IDLH[d]
Regionalized 2								
Hanford	1.0E-4	2.6E-9	4.3E-2	5.3E-7	1.4E-8	2.3E-1	3.4E-5	7.7
INEL	5.0E-5	1.2E-8	1.9E-1	1.1E-4	6.6E-8	1.1	3.1E-5	6.3
LANL	2.2E-5	7.5E-9	1.2E-1	4.3E-6	5.8E-8	9.4E-1	4.5E-6	2.6
ORR	8.9E-3	5.7E-7	9.4	7.6E-4	6.0E-7	9.8	2.5E-4	3.6E1
Ports	1.2E-4	9.0E-8	1.5	5.2E-5	1.5E-7	2.4	4.7E-5	1.1E1
RFETS	4.7E-4	9.5E-9	1.6E-1	4.6E-6	1.2E-8	1.9E-1	4.5E-6	1.8
SRS	1.6E-5	5.2E-9	8.6E-2	7.3E-5	2.9E-7	4.7	5.9E-5	1.4E1
Regionalized 4								
Hanford	1.0E-4	2.6E-9	4.3E-2	5.3E-7	1.4E-8	2.3E-1	3.2E-5	7.7
INEL	7.2E-5	1.7E-8	2.8E-1	1.7E-4	9.5E-8	1.6	4.9E-5	8.7
ORR	1.1E-2	7.3E-7	1.2E1	9.7E-4	7.7E-7	1.3E1	3.6E-4	4.6E1
SRS	1.6E-5	5.2E-9	8.6E-2	7.3E-5	2.9E-7	4.7	6.4E-5	1.4E1
Centralized								
Hanford	1.0E-3	2.6E-8	4.3E-1	5.2E-6	1.4E-7	2.3	7.5E-4	6.8E1

[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] CI—risk of cancer incidence associated with exposure to carcinogenic chemicals.
[c] HI—hazard index.
[d] IDLH—worker IDLH index.

Table D.3.5–39. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the No Action Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Incinerator Explosion (A)[d]	7.8E-7	8.9E-11	8.6E-5	2.7E-6	3.0E-10	3.0E-4
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	2.0E-5	2.2E-9	2.1E-6	6.6E-5	7.6E-9	7.5E-6
Non-Alpha Incineration, Earthquake (VU)	1.3E-3	1.5E-7	1.4E-4	4.4E-3	5.0E-7	5.0E-4
WORST-CASE ACCIDENT	1.3E-3	1.5E-7	1.4E-4	4.4E-3	5.0E-7	5.0E-4

[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-6).

Table D.3.5–40. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the No Action Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	1.6E-1	1.4E-5	9.8E-3	5.5E-1	4.7E-5	3.4E-2
Non-Alpha Incineration, Incinerator Explosion (A)	9.7E-5	8.2E-9	5.9E-3	3.3E-4	2.8E-8	2.1E-2
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	2.4E-3	2.1E-7	1.5E-4	8.2E-3	7.0E-7	5.1E-4
WORST-CASE ACCIDENT	1.6E-1	1.4E-5	9.8E-3	5.5E-1	4.7E-5	3.4E-2

[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-6).

Table D.3.5–41. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the No Action Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2
Non-Alpha Incineration, Incinerator Explosion (A)	1.2E-5	3.6E-10	1.9E-3	4.0E-5	1.2E-9	6.7E-3
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	3.0E-4	9.1E-9	4.8E-5	1.0E-3	3.1E-8	1.7E-4
WORST-CASE ACCIDENT	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2

[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-6).

Table D.3.5–42. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ANL-E Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Incinerator Explosion (A)[d]	3.7E-5	1.1E-9	5.3E-4	1.2E-4	3.7E-9	1.8E-3
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	9.1E-4	2.7E-8	1.3E-5	3.1E-3	9.3E-8	4.6E-5
Non-Alpha Incineration, Earthquake (VU)	6.1E-2	1.8E-6	8.8E-4	2.1E-1	6.2E-6	3.1E-3
WORST-CASE ACCIDENT	6.1E-2	1.8E-6	8.8E-4	2.1E-1	6.2E-6	3.1E-3

[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-6).

Table D.3.5–43. Radionuclide-Related Accident Risks Associated With LLMW Treatment at BNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Incinerator Explosion (A)[d]	6.1E-6	5.5E-10	5.6E-6	2.1E-5	1.9E-9	1.9E-5
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	1.5E-4	1.4E-8	1.4E-7	5.2E-4	4.7E-8	4.9E-7
Non-Alpha Incineration, Earthquake (VU)	1.0E-2	9.2E-7	9.3E-6	3.5E-2	3.1E-6	3.2E-5
WORST-CASE ACCIDENT	1.0E-2	9.2E-7	9.3E-6	3.5E-2	3.1E-6	3.2E-5

[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-6).

Table D.3.5–44. Radionuclide-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	1.6E-5	4.1E-9	7.0E-8	5.4E-5	1.4E-8	2.5E-7
Non-Alpha Incineration, Incinerator Explosion (A)	9.5E-9	2.5E-12	4.2E-8	3.2E-8	8.4E-12	1.5E-7
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	2.4E-7	6.2E-11	1.1E-9	8.1E-7	2.1E-10	3.7E-9
WORST-CASE ACCIDENT	1.6E-5	4.1E-9	7.0E-8	5.4E-5	1.4E-8	2.5E-7

[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-6).

Table D.3.5–45. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2
Non-Alpha Incineration, Incinerator Explosion (A)	1.6E-4	3.8E-9	6.5E-3	5.5E-4	1.3E-8	2.3E-2
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	4.0E-3	9.5E-8	1.6E-4	1.4E-2	3.2E-7	5.7E-4
WORST-CASE ACCIDENT	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2

[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-6).

Table D.3.5–46. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2
Alpha Incineration, Incinerator Explosion (A)	1.3E-6	1.4E-10	1.8E-3	4.3E-6	4.9E-10	6.4E-3
Alpha Incineration, Feedstock Staging Area Fire (U)	3.1E-5	3.6E-9	4.6E-5	1.1E-4	1.2E-8	1.6E-4
Non-Alpha Incineration, Earthquake (VU)	1.3E-3	1.5E-7	1.4E-4	4.5E-3	5.1E-7	5.1E-4
Non-Alpha Incineration, Incinerator Explosion (A)	7.9E-7	9.0E-11	8.7E-5	2.7E-6	3.1E-10	3.0E-4
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	2.0E-5	2.3E-9	2.2E-6	6.7E-5	7.7E-9	7.6E-6
WORST-CASE ACCIDENT	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2

[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-6).

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Table D.3.5–47. Radionuclide-Related Accident Risks Associated With LLMW Treatment at KAPL-K Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	4.1E-3	2.1E-7	5.7E-6	1.4E-2	7.0E-7	2.0E-5
Non-Alpha Incineration, Incinerator Explosion (A)	2.5E-6	1.2E-10	3.4E-6	8.4E-6	4.2E-10	1.2E-5
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	6.2E-5	3.1E-9	8.6E-8	2.1E-4	1.1E-8	3.0E-7
WORST-CASE ACCIDENT	4.1E-3	2.1E-7	5.7E-6	1.4E-2	7.0E-7	2.0E-5

[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-6).

Table D.3.5–48. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	1.1E-2	1.6E-6	1.3E-4	3.8E-2	5.3E-6	4.7E-4
Alpha Incineration, Incinerator Explosion (A)	6.8E-6	9.3E-10	8.0E-5	2.3E-5	3.2E-9	2.8E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	1.7E-4	2.3E-8	2.0E-6	5.8E-4	7.9E-8	7.0E-6
WORST-CASE ACCIDENT	1.1E-2	1.6E-6	1.3E-4	3.8E-2	5.3E-6	4.7E-4

[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-6).

Table D.3.5–49. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4
Alpha Incineration, Incinerator Explosion (A)	5.4E-7	2.6E-10	1.0E-4	1.9E-6	8.8E-10	3.6E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	1.4E-5	6.5E-9	2.6E-6	4.6E-5	2.2E-8	9.0E-6
WORST-CASE ACCIDENT	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4

[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-6).

Table D.3.5–50. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	1.6E-1	1.4E-5	1.1E-2	5.5E-1	4.7E-5	3.9E-2
Non-Alpha Incineration, Incinerator Explosion (A)	9.7E-5	8.2E-9	6.6E-3	3.3E-4	2.8E-8	2.3E-2
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	2.4E-3	2.1E-7	1.7E-4	8.2E-3	7.0E-7	5.8E-4
WORST-CASE ACCIDENT	1.6E-1	1.4E-5	1.1E-2	5.5E-1	4.7E-5	3.9E-2

[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-6).

Table D.3.5–51. Radionuclide-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	3.1E-2	9.0E-6	2.3E-3	1.1E-1	3.1E-5	8.2E-3
Non-Alpha Incineration, Incinerator Explosion (A)	1.9E-5	5.4E-9	1.4E-3	6.3E-5	1.8E-8	4.9E-3
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	4.6E-4	1.4E-7	3.5E-5	1.6E-3	4.6E-7	1.2E-4
WORST-CASE ACCIDENT	3.1E-2	9.0E-6	2.3E-3	1.1E-1	3.1E-5	8.2E-3

[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-6).

Table D.3.5–52. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	5.1E-4	5.6E-8	5.2E-6	1.7E-3	1.9E-7	1.8E-5
Non-Alpha Incineration, Incinerator Explosion (A)	3.1E-7	3.3E-11	3.1E-6	1.0E-6	1.1E-10	1.1E-5
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	7.7E-6	8.3E-10	7.8E-8	2.6E-5	2.8E-9	2.7E-7
WORST-CASE ACCIDENT	5.1E-4	5.6E-8	5.2E-6	1.7E-3	1.9E-7	1.8E-5

[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-6).

Table D.3.5–53. Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3
Alpha Incineration, Incinerator Explosion (A)	3.5E-6	1.3E-10	2.4E-4	1.2E-5	4.3E-10	8.3E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	8.8E-5	3.1E-9	5.9E-6	3.0E-4	1.1E-8	2.1E-5
WORST-CASE ACCIDENT	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3

[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-6).

Table D.3.5-54. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	1.7E-3	5.3E-8	1.4E-4	5.9E-3	1.8E-7	4.9E-4
Alpha Incineration, Incinerator Explosion (A)	1.0E-6	3.2E-11	8.4E-5	3.5E-6	1.1E-10	2.9E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	2.6E-5	8.0E-10	2.1E-6	8.8E-5	2.7E-9	7.3E-6
Non-Alpha Incineration, Earthquake (VU)	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2
Non-Alpha Incineration, Incinerator Explosion (A)	1.2E-5	3.6E-10	1.9E-3	4.0E-5	1.2E-9	6.7E-3
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	3.0E-4	9.1E-9	4.8E-5	1.0E-3	3.1E-8	1.7E-4
WORST-CASE ACCIDENT	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2

[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-6).

Table D.3.5–55. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Incinerator Explosion (A)[d]	1.3E-6	1.4E-10	1.8E-3	4.3E-6	4.9E-10	6.4E-3
Alpha Incineration, Feedstock Staging Area Fire (U)	3.1E-5	3.6E-9	4.6E-5	1.1E-4	1.2E-8	1.6E-4
Alpha Incineration, Earthquake (VU)	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2
WORST-CASE ACCIDENT	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2

[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-6).

Table D.3.5-56. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	1.1E-2	1.6E-6	1.3E-4	3.8E-2	5.3E-6	4.7E-4
Alpha Incineration, Incinerator Explosion (A)	6.8E-6	9.3E-10	8.0E-5	2.3E-5	3.2E-9	2.8E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	1.7E-4	2.3E-8	2.0E-6	5.8E-4	7.9E-8	7.0E-6
WORST-CASE ACCIDENT	1.1E-2	1.6E-6	1.3E-4	3.8E-2	5.3E-6	4.7E-4

[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-6).

Table D.3.5-57. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4
Alpha Incineration, Incinerator Explosion (A)	5.4E-7	2.6E-10	1.0E-4	1.9E-6	8.8E-10	3.6E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	1.4E-5	6.5E-9	2.6E-6	4.6E-5	2.2E-8	9.0E-6
WORST-CASE ACCIDENT	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4

[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-6).

Table D.3.5-58. Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3
Alpha Incineration, Incinerator Explosion (A)	3.5E-6	1.3E-10	2.4E-4	1.2E-5	4.3E-10	8.3E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	8.8E-5	3.1E-9	5.9E-6	3.0E-4	1.1E-8	2.1E-5
WORST-CASE ACCIDENT	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3

[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-6).

Table D.3.5-59. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	1.7E-3	5.3E-8	1.4E-4	5.9E-3	1.8E-7	4.9E-4
Alpha Incineration, Incinerator Explosion (A)	1.0E-6	3.2E-11	8.4E-5	3.5E-6	1.1E-10	2.9E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	2.6E-5	8.0E-10	2.1E-6	8.8E-5	2.7E-9	7.3E-6
WORST-CASE ACCIDENT	1.7E-3	5.3E-8	1.4E-4	5.9E-3	1.8E-7	4.9E-4

[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-6).

Table D.3.5-60. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2
Non-Alpha Incineration, Incinerator Explosion (A)	1.6E-4	3.8E-9	6.5E-3	5.5E-4	1.3E-8	2.3E-2
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	4.0E-3	9.5E-8	1.6E-4	1.4E-2	3.2E-7	5.7E-4
WORST-CASE ACCIDENT	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2

[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-6).

Table D.3.5-61. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Incinerator Explosion (A)[d]	1.3E-6	1.4E-10	1.8E-3	4.3E-6	4.9E-10	6.4E-3
Alpha Incineration, Feedstock Staging Area Fire (U)	3.1E-5	3.6E-9	4.6E-5	1.1E-4	1.2E-8	1.6E-4
Non-Alpha Incineration, Incinerator Explosion (A)	7.9E-7	9.0E-11	1.7E-4	2.7E-6	3.1E-10	6.1E-4
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	2.0E-5	2.3E-9	4.3E-6	6.7E-5	7.7E-9	1.5E-5
Alpha Incineration, Earthquake (VU)	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2
Non-Alpha Incineration, Earthquake (VU)	1.3E-3	1.5E-7	2.9E-4	4.5E-3	5.1E-7	1.0E-3
WORST-CASE ACCIDENT	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2

[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-6).

Table D.3.5-62. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Incinerator Explosion (A)[d]	5.4E-7	2.6E-10	1.0E-4	1.9E-6	8.8E-10	3.6E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	1.4E-5	6.5E-9	2.6E-6	4.6E-5	2.2E-8	9.0E-6
Non-Alpha Incineration, Earthquake (VU)	4.8E-4	2.3E-7	9.3E-6	1.7E-3	7.8E-7	3.3E-5
Non-Alpha Incineration, Incinerator Explosion (A)	2.9E-7	1.4E-10	5.6E-6	9.9E-7	4.7E-10	2.0E-5
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	7.3E-6	3.5E-9	1.4E-7	2.5E-5	1.2E-8	4.9E-7
Alpha Incineration, Earthquake (VU)	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4
WORST-CASE ACCIDENT	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4

[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-6).

Table D.3.5-63. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	1.8E-1	1.5E-5	1.6E-2	6.1E-1	5.1E-5	5.7E-2
Non-Alpha Incineration, Incinerator Explosion (A)	1.1E-4	9.0E-9	9.8E-3	3.6E-4	3.1E-8	3.4E-2
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	2.7E-3	2.3E-7	2.4E-4	9.1E-3	7.6E-7	8.5E-4
WORST-CASE ACCIDENT	1.8E-1	1.5E-5	1.6E-2	6.1E-1	5.1E-5	5.7E-2

[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-6).

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Table D.3.5-64. Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	1.5E-4	5.5E-9	4.0E-7	5.3E-4	1.9E-8	1.4E-6
Alpha Incineration, Incinerator Explosion (A)	3.5E-6	1.3E-10	2.4E-4	1.2E-5	4.3E-10	8.3E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	8.8E-5	3.1E-9	5.9E-6	3.0E-4	1.1E-8	2.1E-5
Alpha Incineration, Earthquake (VU)	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3
Non-Alpha Incineration, Incinerator Explosion (A)	9.3E-8	3.3E-12	2.4E-7	3.2E-7	1.1E-11	8.5E-7
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	2.3E-6	8.3E-11	6.0E-9	7.9E-6	2.8E-10	2.1E-8
WORST-CASE ACCIDENT	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3

[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-6).

Table D.3.5-65. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	1.7E-3	5.3E-8	1.4E-4	5.9E-3	1.8E-7	4.9E-4
Alpha Incineration, Incinerator Explosion (A)	1.0E-6	3.2E-11	8.4E-5	3.5E-6	1.1E-10	2.9E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	2.6E-5	8.0E-10	2.1E-6	8.8E-5	2.7E-9	7.3E-6
Non-Alpha Incineration, Earthquake (VU)	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2
Non-Alpha Incineration, Incinerator Explosion (A)	1.2E-5	3.7E-10	1.9E-3	4.0E-5	1.3E-9	6.7E-3
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	3.0E-4	9.2E-9	4.8E-5	1.0E-3	3.1E-8	1.7E-4
WORST-CASE ACCIDENT	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2

[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-6).

Table D.3.5–66. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2
Non-Alpha Incineration, Incinerator Explosion (A)	1.6E-4	3.8E-9	6.5E-3	5.5E-4	1.3E-8	2.3E-2
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	4.0E-3	9.5E-8	1.6E-4	1.4E-2	3.2E-7	5.7E-4
WORST-CASE ACCIDENT	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2

[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-6).

Table D.3.5–67. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	2.1E-3	2.4E-7	3.5E-3	7.1E-3	8.1E-7	1.2E-2
Alpha Incineration, Incinerator Explosion (A)	1.3E-6	1.4E-10	2.1E-3	4.3E-6	4.9E-10	7.4E-3
Alpha Incineration, Feedstock Staging Area Fire (U)	3.1E-5	3.6E-9	5.3E-5	1.1E-4	1.2E-8	1.9E-4
Non-Alpha Incineration, Earthquake (VU)	1.3E-3	1.5E-7	4.4E-4	4.5E-3	5.1E-7	1.5E-3
Non-Alpha Incineration, Incinerator Explosion (A)	7.9E-7	9.0E-11	2.6E-4	2.7E-6	3.1E-10	9.1E-4
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	2.0E-5	2.3E-9	6.5E-6	6.7E-5	7.7E-9	2.3E-5
WORST-CASE ACCIDENT	2.1E-3	2.4E-7	3.5E-3	7.1E-3	8.1E-7	1.2E-2

[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-6).

Table D.3.5–68. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	1.8E-1	1.6E-5	1.4E-2	6.2E-1	5.3E-5	5.0E-2
Non-Alpha Incineration, Incinerator Explosion (A)	1.1E-4	9.4E-9	8.5E-3	3.7E-4	3.2E-8	3.0E-2
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	2.8E-3	2.3E-7	2.1E-4	9.3E-3	8.0E-7	7.4E-4
WORST-CASE ACCIDENT	1.8E-1	1.6E-5	1.4E-2	6.2E-1	5.3E-5	5.0E-2

[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-6).

Table D.3.5-69. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	1.7E-3	5.3E-8	1.4E-4	5.9E-3	1.8E-7	4.9E-4
Alpha Incineration, Incinerator Explosion (A)	1.0E-6	3.2E-11	8.4E-5	3.5E-6	1.1E-10	2.9E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	2.6E-5	8.0E-10	2.1E-6	8.8E-5	2.7E-9	7.3E-6
Non-Alpha Incineration, Earthquake (VU)	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2
Non-Alpha Incineration, Incinerator Explosion (A)	1.2E-5	3.7E-10	1.9E-3	4.0E-5	1.3E-9	6.7E-3
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	3.0E-4	9.2E-9	4.8E-5	1.0E-3	3.1E-8	1.7E-4
WORST-CASE ACCIDENT	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2

[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-6).

Table D.3.5–70. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Centralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, Earthquake (VU)[d]	3.4E-3	8.0E-8	4.5E-4	1.2E-2	2.7E-7	1.6E-3
Non-Alpha Incineration, Earthquake (VU)	4.0E-1	9.4E-6	4.4E-2	1.4	3.2E-5	1.6E-1
Non-Alpha Incineration, Incinerator Explosion (A)	2.4E-4	5.7E-9	2.7E-2	8.2E-4	1.9E-8	9.3E-2
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	6.0E-3	1.4E-7	6.7E-4	2.1E-2	4.8E-7	2.3E-3
Alpha Incineration, Incinerator Explosion (A)	2.0E-6	4.8E-11	2.7E-4	6.9E-6	1.6E-10	9.4E-4
Alpha Incineration, Feedstock Staging Area Fire (U)	5.1E-5	1.2E-9	6.7E-6	1.7E-4	4.1E-9	2.4E-5
WORST-CASE ACCIDENT	4.0E-1	9.4E-6	4.4E-2	1.4	3.2E-5	1.6E-1

[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-6).

Table D.3.5–71. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the No Action Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Worker
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	8.9E-7	2.1E-10	7.5E-8	3.5E-3	1.1
WORST-CASE ACCIDENT	8.9E-7	2.1E-10	7.5E-8	3.5E-3	1.1

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–72. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the No Action Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Worker
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	7.3E-3	4.7E-7	1.9E-4	7.8	3.0E1
WORST-CASE ACCIDENT	7.3E-3	4.7E-7	1.9E-4	7.8	3.0E1

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–73. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the No Action Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Worker
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.5E-5	4.9E-9	6.0E-5	8.1E-2	1.4E1
WORST-CASE ACCIDENT	1.5E-5	4.9E-9	6.0E-5	8.1E-2	1.4E1

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–74. Chemical-Related Accident Risks Associated With LLMW Treatment at ANL-E Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Worker
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	9.3E-6	2.6E-10	3.3E-7	4.2E-3	1.1
WORST-CASE ACCIDENT	9.3E-6	2.6E-10	3.3E-7	4.2E-3	1.1

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–75. Chemical-Related Accident Risks Associated With LLMW Treatment at BNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Worker
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	3.2E-5	5.8E-10	1.8E-8	9.5E-3	1.0
WORST-CASE ACCIDENT	3.2E-5	5.8E-10	1.8E-8	9.5E-3	1.0

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–76. Chemical-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.3E-4	1.0E-8	2.1E-6	1.6E-1	1.9
WORST-CASE ACCIDENT	2.3E-4	1.0E-8	2.1E-6	1.6E-1	1.9

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–77. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	6.5E-5	1.7E-9	2.1E-5	2.8E-2	5.3
WORST-CASE ACCIDENT	6.5E-5	1.7E-9	2.1E-5	2.8E-2	5.3

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–78. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.8E-6	6.8E-10	3.1E-7	1.1E-2	1.3
Alpha Incineration, Feedstock Staging Area Fire (A)	3.5E-5	8.2E-9	1.9E-5	1.3E-1	4.7
WORST-CASE ACCIDENT	3.5E-5	8.2E-9	1.9E-5	1.3E-1	4.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–79. Chemical-Related Accident Risks Associated With LLMW Treatment at KCP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.7E-7	1.2E-11	7.7E-12	2.0E-4	1.0
WORST-CASE ACCIDENT	2.7E-7	1.2E-11	7.7E-12	2.0E-4	1.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–80. Chemical-Related Accident Risks Associated With LLMW Treatment at KAPL-K Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	3.6E-6	6.1E-10	9.3E-9	1.0E-2	1.0
WORST-CASE ACCIDENT	3.6E-6	6.1E-10	9.3E-9	1.0E-2	1.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–81. Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.6E-6	8.7E-10	7.9E-8	1.4E-2	1.2
Alpha Incineration, Feedstock Staging Area Fire (A)	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6
WORST-CASE ACCIDENT	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–82. Chemical-Related Accident Risks Associated With LLMW Treatment at LBL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	5.6E-6	5.1E-10	3.9E-9	8.4E-3	1.0
WORST-CASE ACCIDENT	5.6E-6	5.1E-10	3.9E-9	8.4E-3	1.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–83. Chemical-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	8.8E-5	2.4E-8	6.0E-6	4.0E-1	3.2
Alpha Incineration, Feedstock Staging Area Fire (A)	6.4E-5	1.8E-8	4.7E-6	2.9E-1	2.6
WORST-CASE ACCIDENT	8.8E-5	2.4E-8	6.0E-6	4.0E-1	3.2

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–84. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	8.7E-3	5.6E-7	2.5E-4	9.2	3.6E1
WORST-CASE ACCIDENT	8.7E-3	5.6E-7	2.5E-4	9.2	3.6E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–85. Chemical-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.3E-4	1.9E-8	9.9E-7	3.2E-1	1.8
WORST-CASE ACCIDENT	1.3E-4	1.9E-8	9.9E-7	3.2E-1	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–86. Chemical-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	6.5E-6	4.5E-10	7.0E-7	7.4E-3	1.9
WORST-CASE ACCIDENT	6.5E-6	4.5E-10	7.0E-7	7.4E-3	1.9

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–87. Chemical-Related Accident Risks Associated With LLMW Treatment at Ports Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.1E-4	7.9E-8	3.4E-5	1.3	9.5
WORST-CASE ACCIDENT	1.1E-4	7.9E-8	3.4E-5	1.3	9.5

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-88. Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Alpha Incineration, Feedstock Staging Area Fire (A)[c]	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8
WORST-CASE ACCIDENT	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-89. Chemical-Related Accident Risks Associated With LLMW Treatment at SNL-NM Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	3.5E-6	1.0E-9	4.6E-8	1.7E-2	1.1
WORST-CASE ACCIDENT	3.5E-6	1.0E-9	4.6E-8	1.7E-2	1.1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite
[c] 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-6).

Table D.3.5–90. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.6E-5	5.2E-9	5.9E-5	8.5E-2	1.4E1
Alpha Incineration, Feedstock Staging Area Fire (A)	1.5E-6	4.7E-10	3.2E-6	7.6E-3	2.2
WORST-CASE ACCIDENT	1.6E-5	5.2E-9	5.9E-5	8.5E-2	1.4E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–91. Chemical-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.5E-4	1.1E-8	3.8E-6	1.8E-1	2.0
WORST-CASE ACCIDENT	2.5E-4	1.1E-8	3.8E-6	1.8E-1	2.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-92. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	6.6E-5	1.7E-9	2.2E-5	2.8E-2	5.4
WORST-CASE ACCIDENT	6.6E-5	1.7E-9	2.2E-5	2.8E-2	5.4

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-93. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.8E-6	6.8E-10	3.1E-7	1.1E-2	1.3
Alpha Incineration, Feedstock Staging Area Fire (A)	3.5E-5	8.2E-9	1.9E-5	1.3E-1	4.7
WORST-CASE ACCIDENT	3.5E-5	8.2E-9	1.9E-5	1.3E-1	4.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–94. Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	3.4E-6	1.2E-9	1.1E-7	1.9E-2	1.3
Alpha Incineration, Feedstock Staging Area Fire (A)	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6
WORST-CASE ACCIDENT	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6

[a] Indicates cancer fatalities associated with chemical carcinogen exposure
[b] Offsite.
[c] 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-6).

Table D.3.5–95. Chemical-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	9.1E-5	2.5E-8	6.4E-6	4.1E-1	3.3
Alpha Incineration, Feedstock Staging Area Fire (A)	6.4E-5	1.8E-8	4.7E-6	2.9E-1	2.6
WORST-CASE ACCIDENT	9.1E-5	2.5E-8	6.4E-6	4.1E-1	3.3

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-96. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	8.7E-3	5.6E-7	2.5E-4	9.2	3.6E1
WORST-CASE ACCIDENT	8.7E-3	5.6E-7	2.5E-4	9.2	3.6E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-97. Chemical-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	6.5E-6	4.5E-10	7.0E-7	7.4E-3	1.9
WORST-CASE ACCIDENT	6.5E-6	4.5E-10	7.0E-7	7.4E-3	1.9

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-98. Chemical-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.3E-4	1.9E-8	9.9E-7	3.2E-1	1.8
WORST-CASE ACCIDENT	1.3E-4	1.9E-8	9.9E-7	3.2E-1	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-99. Chemical-Related Accident Risks Associated With LLMW Treatment at Ports Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.1E-4	8.1E-8	3.5E-5	1.3	9.8
WORST-CASE ACCIDENT	1.1E-4	8.1E-8	3.5E-5	1.3	9.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–100. Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.1E-7	4.2E-12	2.7E-12	6.9E-5	1.0
Alpha Incineration, Feedstock Staging Area Fire (A)	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8
WORST-CASE ACCIDENT	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–101. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.6E-5	5.2E-9	5.9E-5	8.6E-2	1.4E1
Alpha Incineration, Baghouse Are Facility Fire (A)	1.5E-6	4.7E-10	3.2E-6	7.6E-3	2.2
WORST-CASE ACCIDENT	1.6E-5	5.2E-9	5.9E-5	8.6E-2	1.4E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–102. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.0E-4	2.6E-9	3.4E-5	4.3E-2	7.7
WORST-CASE ACCIDENT	1.0E-4	2.6E-9	3.4E-5	4.3E-2	7.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–103. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.9E-6	7.0E-10	5.2E-7	1.1E-2	1.3
Alpha Incineration, Feedstock Staging Area Fire (A)	5.0E-5	1.2E-8	3.1E-5	1.9E-1	6.3
WORST-CASE ACCIDENT	5.0E-5	1.2E-8	3.1E-5	1.9E-1	6.3

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–104. Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.6E-5	5.5E-9	1.2E-6	9.0E-2	2.2
Alpha Incineration, Feedstock Staging Area Fire (A)	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6
WORST-CASE ACCIDENT	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–105. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	8.9E-3	5.7E-7	2.5E-4	9.4	3.6E1
WORST-CASE ACCIDENT	8.9E-3	5.7E-7	2.5E-4	9.4	3.6E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-106. Chemical-Related Accident Risks Associated With LLMW Treatment at Ports Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.2E-4	9.0E-8	4.7E-5	1.5	1.1E1
WORST-CASE ACCIDENT	1.2E-4	9.0E-8	4.7E-5	1.5	1.1E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-107. Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	8.0E-7	1.6E-11	2.1E-11	2.6E-4	1.0
Alpha Incineration, Feedstock Staging Area Fire (A)	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8
WORST-CASE ACCIDENT	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-108. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.6E-5	5.2E-9	5.9E-5	8.6E-2	1.4E1
Alpha Incineration, Feedstock Staging Area Fire (A)	1.5E-6	4.7E-10	3.2E-6	7.6E-3	2.2
WORST-CASE ACCIDENT	1.6E-5	5.2E-9	5.9E-5	8.6E-2	1.4E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5-109. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.0E-4	2.6E-9	3.2E-5	4.3E-2	7.7
WORST-CASE ACCIDENT	1.0E-4	2.6E-9	3.2E-5	4.3E-2	7.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–110. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.4E-5	3.4E-9	3.6E-6	5.5E-2	2.5
Alpha Incineration, Feedstock Staging Area Fire (A)	7.2E-5	1.7E-8	4.9E-5	2.8E-1	8.7
WORST-CASE ACCIDENT	7.2E-5	1.7E-8	4.9E-5	2.8E-1	8.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–111. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.1E-2	7.3E-7	3.6E-4	1.2E1	4.6E1
WORST-CASE ACCIDENT	1.1E-2	7.3E-7	3.6E-4	1.2E1	4.6E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–112. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.6E-5	5.2E-9	6.4E-5	8.6E-2	1.4E1
Alpha Incineration, Feedstock Staging Area Fire (A)	1.5E-6	4.7E-10	3.8E-6	7.6E-3	2.2
WORST-CASE ACCIDENT	1.6E-5	5.2E-9	6.4E-5	8.6E-2	1.4E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

Table D.3.5–113. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Centralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.0E-3	2.6E-8	7.5E-4	4.3E-1	6.8E1
Alpha Incineration, Feedstock Staging Area Fire (A)	1.3E-4	3.5E-9	5.7E-5	5.7E-2	9.8
WORST-CASE ACCIDENT	1.0E-3	2.6E-8	7.5E-4	4.3E-1	6.8E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] 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-6).

D.3.5.9 Risks to the Hypothetical Intruder from LLMW Disposal

The health risks to the hypothetical intruder who drills a well through an LLMW disposal facility were evaluated for the Decentralized, Regionalized 2, and Centralized Alternatives, and for remote-handled LLMW (RH-LLMW) disposal (disposal at four installations in the Decentralized, Regionalized, and Centralized Alternatives). Intrusion was evaluated 100 years and 300 years after the cessation of disposal activities at each installation.

Tables D.3.5-114 and D.3.5-115 present summaries of the risk evaluations at 100 and 300 years, respectively. Tables D.3.5-116 through D.3.5-123 contain the health risks by health endpoint and installation for each alternative in both time frames.

Table D.3.5-114. Summary Table for the Intruder Scenario for LLMW (100 years)

Alternative	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Decentralized	34	1.7E-2	5.8E-2	3.4E-3	1.8E-13	1.1E-7
Regionalized 2	33	1.6E-2	5.5E-2	3.3E-3	1.8E-13	1.4E-7
Centralized	7.1	3.6E-3	1.2E-2	7.1E-4	5.1E-14	9.6E-8
RH-LLMW	68	3.3E-2	1.2E-1	6.8E-3	1.2E-14	8.8E-9

Table D.3.5-115. Summary Table for the Intruder Scenario for LLMW (300 years)

Alternative	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Decentralized	7.2E-1	3.5E-4	1.2E-3	7.2E-5	1.8E-13	1.1E-7
Regionalized 2	6.1E-1	3.0E-4	1.0E-3	6.1E-5	1.8E-13	1.4E-7
Centralized	1.5E-1	7.3E-5	2.5E-4	1.5E-5	5.1E-14	9.6E-8
RH-LLMW	2.2	1.1E-3	3.7E-3	2.2E-4	1.2E-14	8.8E-9

Table D.3.5-116. Intruder Scenario Risk Results for the Decentralized Alternative (100 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
ANL-E	6.6E-1	3.3E-4	1.1E-3	6.6E-5	1.4E-14	1.6E-8
BNL	1.5E-2	7.4E-6	2.5E-5	1.5E-6	0.0	1.3E-9
FEMP	1.4E-3	6.8E-7	2.3E-6	1.4E-7	0.0	6.8E-9
Hanford	19	9.4E-3	3.2E-2	1.9E-3	3.1E-14	4.0E-8
INEL	7.5	3.8E-3	1.3E-2	7.5E-4	2.2E-14	6.2E-8
LANL	5.2E-2	2.6E-5	8.8E-5	5.2E-6	0.0	1.0E-8
LLNL	3.2E-1	1.6E-4	5.4E-4	3.2E-5	0.0	1.6E-8
NTS	4.9E-2	2.4E-5	8.3E-5	4.9E-6	0.0	6.7E-9
ORR	2.6	1.3E-3	4.4E-3	2.6E-4	4.8E-14	1.1E-7
PGDP	1.3E-1	6.4E-5	2.2E-4	1.3E-5	0.0	2.5E-9
Pantex	1.9E-2	9.4E-6	3.2E-5	1.9E-6	0.0	8.6E-10
PORTS	4.8E-1	2.4E-4	8.2E-4	4.8E-5	2.7E-14	2.9E-8
RFETS	1.6E-2	7.8E-6	2.6E-5	1.6E-6	1.3E-14	5.4E-9
SNL-NM	1.1E-2	5.6E-6	1.9E-5	1.1E-6	0.0	4.9E-11
SRS	3.1	1.6E-3	5.4E-3	3.1E-4	2.8E-14	1.0E-7
TOTAL	34	1.7E-2	5.8E-2	3.4E-3	1.8E-13	1.1E-7

Table D.3.5–117. Intruder Scenario Risk Results for the Decentralized Alternative (300 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
ANL–E	2.3E-2	1.1E-5	3.9E-5	2.3E-6	1.4E-14	1.6E-8
BNL	5.0E-4	2.5E-7	8.6E-7	5.0E-8	0.0	1.3E-9
FEMP	1.4E-3	6.8E-7	2.3E-6	1.4E-7	0.0	6.8E-9
Hanford	1.5E-1	7.7E-5	2.6E-4	1.5E-5	3.1E-14	4.0E-8
INEL	2.5E-1	1.2E-4	4.2E-4	2.5E-5	2.2E-14	6.2E-8
LANL	1.9E-3	9.3E-7	3.2E-6	1.9E-7	0.0	1.0E-8
LLNL	9.3E-3	4.6E-6	1.6E-5	9.3E-7	0.0	1.6E-8
NTS	3.1E-3	1.6E-6	5.3E-6	3.1E-7	0.0	6.7E-9
ORR	8.5E-2	4.2E-5	1.4E-4	8.5E-6	4.8E-14	1.1E-7
PGDP	1.3E-1	6.4E-5	2.2E-4	1.3E-5	0.0	2.5E-9
Pantex	1.9E-4	9.3E-8	3.2E-7	1.9E-8	0.0	8.6E-10
PORTS	6.0E-3	3.0E-6	1.0E-5	6.0E-7	2.7E-14	2.9E-8
RFETS	1.1E-2	5.7E-6	1.9E-5	1.1E-6	1.3E-14	5.4E-9
SNL–NM	1.6E-4	8.2E-8	2.8E-7	1.6E-8	0.0	4.9E-11
SRS	4.6E-2	2.3E-5	7.9E-5	4.6E-6	2.8E-14	1.0E-7
TOTAL	7.2E-1	3.5E-4	1.2E-3	7.2E-5	1.8E-13	1.1E-7

Table D.3.5–118. Intruder Scenario Risk Results for the Regionalized Alternative 2 (100 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	19	9.4E-3	3.2E-2	1.9E-3	3.4E-14	4.7E-8
INEL	7.9	3.9E-3	1.3E-2	7.9E-4	2.7E-14	6.9E-8
LANL	4.6E-2	2.3E-5	7.9E-5	4.6E-6	1.7E-14	1.1E-8
NTS	1.4E-4	7.1E-8	2.4E-7	1.4E-8	0.0	2.8E-12
ORR	2.5	1.2E-3	4.2E-3	2.5E-4	7.1E-14	1.4E-7
SRS	3.1	1.6E-3	5.4E-3	3.1E-4	2.7E-14	1.0E-7
TOTAL	33	1.6E-2	5.5E-2	3.3E-3	1.8E-13	1.4E-7

Table D.3.5–119. Intruder Scenario Risk Results for the Regionalized Alternative 2 (300 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	1.4E-1	7.1E-5	2.4E-4	1.4E-5	3.4E-14	4.7E-8
INEL	2.6E-1	1.3E-4	4.4E-4	2.6E-5	2.7E-14	6.9E-8
LANL	1.4E-2	6.8E-6	2.3E-5	1.4E-6	1.7E-14	1.1E-8
NTS	3.4E-4	1.7E-8	5.8E-8	3.4E-9	0.0	2.8E-12
ORR	1.5E-1	7.4E-5	2.5E-4	1.5E-5	7.1E-14	1.4E-7
SRS	4.6E-2	2.3E-5	7.9E-5	4.6E-6	2.7E-14	1.0E-7
TOTAL	6.1E-1	3.0E-4	1.0E-3	6.1E-5	1.8E-13	1.4E-7

Table D.3.5–120. Intruder Scenario Risk Results for the Centralized Alternative (100 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	7.1	3.6E-3	1.2E-2	7.1E-4	5.1E-14	9.6E-8
TOTAL	7.1	3.6E-3	1.2E-2	7.1E-4	5.1E-14	9.6E-8

Table D.3.5–121. Intruder Scenario Risk Results for the Centralized Alternative (300 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	1.5E-1	7.3E-5	2.5E-4	1.5E-5	5.1E-14	9.6E-8
TOTAL	1.5E-1	7.3E-5	2.5E-4	1.5E-5	5.1E-14	9.6E-8

Table D.3.5–122. Intruder Scenario Risk Results for RH-LLMW (100 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	6.2E-3	3.1E-6	1.0E-5	6.2E-7	0.0	5.9E-13
INEL	13	6.4E-3	2.2E-2	1.3E-3	1.2E-14	8.8E-9
ORR	55	2.7E-2	9.3E-2	5.5E-3	0.0	2.3E-10
SRS	7.0E-2	3.5E-5	1.2E-4	7.0E-6	0.0	6.8E-11
TOTAL	68	3.3E-2	1.2E-1	6.8E-3	1.2E-14	8.8E-9

Table D.3.5-123. Intruder Scenario Risk Results for RH-LLMW (300 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	4.7E-5	2.4E-8	8.1E-8	4.7E-9	0.0	5.9E-13
INEL	2.8E-1	1.4E-4	4.8E-4	2.8E-5	1.2E-14	8.8E-9
ORR	1.9	9.5E-4	3.2E-3	1.9E-4	0.0	2.3E-10
SRS	1.0E-3	5.2E-7	1.8E-6	1.0E-7	0.0	6.8E-11
TOTAL	2.2	1.1E-3	3.7E-3	2.2E-4	1.2E-14	8.8E-9

D.3.5.9.1 *Results of the Human Health Risk Analysis for the Intruder*

For the Decentralized Alternative (which entails disposal at 15 installations), 100 years after the end of disposal operations, the installation with the highest intruder cancer fatality risk is Hanford (9.4E-3) and the lowest cancer fatality risk is at FEMP (6.8E-7). The high dose at Hanford is due to large inventories of Sr-90 and Cs-137. Three hundred years after waste disposal is completed, the highest intruder cancer fatality risk is at INEL (1.2E-4), due primarily to a large inventory of Ni-63, and the lowest risk is at SNL-NM (8.2E-8).

For Regionalized Alternative 2 (involving disposal at six installations), 100 years following the end of disposal, the highest intruder cancer fatality risk is at Hanford (9.4E-3) due to Sr-90 and Cs-137; the lowest intruder risk is at NTS (7.1E-8). Three hundred years after disposal, the highest intruder cancer fatality risk is at INEL (1.3E-4), where Ni-63 is the driving radionuclide; the lowest risk is at NTS (1.7E-8).

The Centralized Alternative (in which all waste is disposed at Hanford) poses an intruder cancer fatality risk of 3.6E-3 at 100 years, following the end of disposal activities. The controlling radionuclide is Sr-90. Three hundred years after disposal, the cancer fatality risk to the intruder decreases to 7.3E-5. The risks at Hanford under this single-installation consolidation alternative are nearly three times lower than the risks at Hanford under the 15- or 6-installation disposal options. While this may seem counterintuitive at first, it derives from the reduction in *average* waste concentration at Hanford that

results when the waste volumes of low-activity wastes from other installations are added to the relatively higher-activity Hanford wastes.

For the RH-LLMW disposal scenario, 100 years after disposal operations cease, the highest cancer fatality risk is at ORR (2.7E-2) due to the presence of Sr-90 in the inventory. The lowest cancer fatality risk occurs at Hanford (3.1E-6). Three hundred years after the end of disposal operations, the highest intruder cancer fatality risk remains at ORR (9.5E-4), due to Th-232, and the lowest risk remains at Hanford (2.4E-8). The driving radionuclide at ORR changes between the 100- and 300-year intrusions because Sr-90 decays through about 10 half-lives in the intervening 200 years whereas, Th-232 has a half-life of approximately 14.1 billion years. As such, more than 99.99% of the material that was present at the close of disposal activities has decayed to lower-risk daughter products.

In general, the risks associated with intrusion at 300 years after closure of the disposal facility are less than those at 100 years due to the decay of radionuclides with time. The incidence of cancer associated with chemical exposures is eight to 12 eight orders of magnitude lower than the risk from exposure to radionuclides, and is well below levels of risk considered to be tolerable. The highest hazard index for any installation is in the E-7 range, so exposure to noncarcinogenic chemicals is unlikely to lead to adverse health effects.

D.4 Uncertainty

The risks presented in the preceding sections of the PEIS will be used to rank the alternatives based on cost, health risk reduction, and environmental and socioeconomic impacts. These risks were calculated based on assumptions about the amount of contaminants released into the environment (source terms), the transport of the contaminants through the air and groundwater to various populations, and the health effects to man resulting from the intake of these contaminants by inhalation or ingestion. These assumptions are necessary because the actual processes may be too complex to simulate or insufficient information is available to properly model the system. Because exact system definition is not possible, a *range* of possible values can be estimated; the most likely value (based on available data) is then chosen for calculating the risk. This range of possible values and the frequency with which these values occur are referred to as the "distribution." The model can be run using this distribution of input parameters to determine the range of risk estimates. This range is known as the risk uncertainty.

The risk uncertainty can be applied to the risk values given in the PEIS to get an estimated range of risks for each alternative. If part of the range of risks for one alternative overlaps the range for another alternative, it may not be possible to make a distinction between the two alternatives to determine which alternative poses the lower risk.

The standard method for determining risk uncertainties is quantitative, and involves estimating the range and distribution of each input parameter, producing a large number of input data sets that simulate those ranges and distributions, then running the model to determine the range of risks that result. However, the PEIS uses too many involves too many parameters and data sets for such an uncertainty analysis. Therefore, a qualitative uncertainty analysis was performed to assess the general accuracy of the PEIS risk estimates. This was done by performing an uncertainty analysis on a limited amount of data, then applying the results across all installations and alternatives.

As noted in previous sections, the uncertainties associated with risk analyses depend to a large degree on the various assumptions that are made when determining model methodologies, scenario definitions, and input parameters. Model uncertainties vary according to the model being used and how applicable that model is to the scenario; they are estimated during the verification and validation phase of model development. Usually, the model developers provide the model uncertainties and/or limitations of model applicability.

Scenario uncertainties include overlooking important receptors, not fully considering receptor activities (which could, for instance, lead to under- or overestimates of exposure), and so forth. Since the PEIS defines the scenarios to be analyzed for risk, these types of uncertainties do not apply in the alternative comparisons and, therefore, were not included in the uncertainty analysis.

Parameter uncertainties are caused by errors in measurements of the independent variables involved in the risk calculations and/or the representativeness of the samples taken for measurement. Since the PEIS is concerned with the comparison of *relative* risk estimates, only the parameters that cause a *relative* uncertainty between alternatives should be included. These parameters generally include all site-specific variables such as wind conditions or crop yields, as opposed to parameters that are common across all facilities, such as the breathing rate of humans and toxicity-related measures such as dose conversion factors.

The first step in this uncertainty analysis requires determining which parameters are significant, that is, which ones have the greatest influence on risk. Parameters that do not contribute to relative errors have been excluded from this uncertainty analysis, and are discussed in greater detail where appropriate in the following sections. The second step involves determining the uncertainty of each significant parameter. The third and final step is calculating the total risk uncertainty. Since different mathematical models are used for treatment and storage sites, disposal facilities, and waste management workers, the analysis will vary for each alternative. Uncertainties are presented in the following text, first for treatment and storage sites, then for disposal sites, and finally for waste management workers.

D.4.1 Treatment and Storage Sites

Atmospheric transport and subsequent inhalation, ingestion, and external exposure to contaminants were considered to be the only significant exposure pathways for treatment and storage sites (the groundwater and surface water transport pathways were excluded). To determine unit doses for the PEIS for radionuclides, the GENII code (Napier et al., 1988) was used. For hazardous chemicals, the ISC2 dispersion models (EPA, 1992) were used. The risk uncertainty from using each of these codes had to be evaluated separately. To determine the general trends and magnitudes in risk uncertainty, a single, quantitative uncertainty analysis was performed using representative data from various sites. The results of this analysis are discussed according to their applicability across all installations.

To perform the uncertainty analysis for the PEIS, the measurement uncertainty and/or representativeness of the samples of all parameters having a significant influence on risk are needed. One significant variable is the source term. However, the uncertainties of the source terms for the PEIS were not provided by ANL at the time of this study and were, therefore, not included in this uncertainty analysis.

The uncertainties of other parameters, such as dose conversion factors, risk factors, and RfDs are associated with a high level of uncertainty. However, these parameters are determined apart from the PEIS and remain constant; therefore, any error associated with them is systematically applied across all facilities. In addition, although the health effects vary for each individual for a given exposure, the overall effects averaged across an entire population should be similar from one facility to another if that population is sufficiently large. Since the assumption that the populations were sufficiently large at all facilities was considered appropriate for a qualitative uncertainty analysis, the uncertainties from these

parameters were not included in this study. The breathing rate of humans was also not considered in this analysis for similar reasons. Other parameters such as particle deposition velocity, resuspension parameters, stack flow rate, and stack exhaust gas temperature were assumed to be identical at all treatment and storage facilities since the facilities are not yet built and are hypothetical in nature. Therefore, these parameters were not included in this uncertainty analysis.

D.4.1.1 Radionuclides

To calculate the uncertainty associated with the estimated exposure caused by radionuclides, a sensitivity analysis of the GENII model was performed first, then the uncertainty analysis was made using only the significant parameters. The results are presented in the following subsections.

D.4.1.1.1 *Sensitivity Analysis of GENII*

A sensitivity analysis was performed to determine the variables that have a significant influence on the model's predictions of risk. Variables that were included in the sensitivity study included average air concentrations from a unit source for a specific area and population (called "Chi/Q"), agricultural yields, and what are termed "dietary fractions" (the rates at which a receptor consumes various nutrients such as water, grain, etc.). As noted in Section D.4.1, other variables such as breathing rates, particle deposition velocities, etc., were not included.

The GENII-S code (Leigh et al., 1992), developed by SNL-NM specifically for sensitivity and uncertainty analysis, was used to perform the sensitivity studies. The uncertainty associated with the annual effective dose equivalent (AEDE) due to the uncertainties associated with input parameters was determined. Latin Hypercube sampling (Iman and Shortencarier, 1984) was used to generate a total of 300 input data sets that represent the distributions of the input variables. The results were subjected to regression analysis so that the statistically significant predictor variables could be determined. The regression equation simply fits a linear curve to the outputs from the Latin Hypercube samples:

$$Y = b + c_1 x_1 + c_2 x_2 + \cdots + c_i x_i$$

where Y is the predicted variable, b is the y intercept, x is the predictor variable, and c is the coefficient of the predictor variable in the linear formula. The null hypothesis that a coefficient was zero was tested to within the 95% confidence level; in other words, any coefficient that had a probability less than 0.05 of being zero was considered a significant parameter.

The parameters used in the sensitivity study included Chi/Q, 11 crop yields, and dietary fractions of cattle. To perform the sensitivity study, the range and distribution of each parameter had to be determined. To initialize input parameters, SRS was chosen as the installation and a representative source term consisting of 1 Ci of each of the following radionuclides was used: tritium, carbon-14, phosphorus-32, sulfur-35, cobalt-60, strontium-90, yttrium-90, technetium-99), ruthenium-106, iodine-125, iodine-129), iodine-135, cesium-137, neptunium-237, thorium-229, uranium-238, americium-242, plutonium-238, and curium-245.

GENII-S uses Chi/Q as an input parameter. However, Chi/Q is actually a derived variable based on the joint frequency data, anemometer height, exhaust stack height, stack flow rate, stack diameter, and stack exhaust gas temperature; therefore, the uncertainty of Chi/Q had to be determined. Only the uncertainty in the site-specific joint frequency data was included in determining the uncertainty of Chi/Q, since the other parameters were not addressed (refer to Section D.4.1).

The joint frequency data for the 26 installations analyzed in the PEIS were collected from the MEPAS code (Droppo et al., 1989) (21 sites), the National Climatic Data Center (4 sites), and an environmental impact statement report (1 site). The joint frequency data comprise six wind speed ranges, seven stability classes per wind speed range (these stability classes indicate the number and intensity of wind gusts for a particular average wind speed range), and 16 wind directions (16 sectors of 22.5 degrees per sector; e.g., north, north-northeast, northeast, east-northeast, etc.). The uncertainties associated with each joint frequency data set are the measurement uncertainties for wind speed and direction and the representativeness of that data set relative to average wind conditions at the site over a specified period of time. The time period of interest may differ for the release scenario. For a chronic release, the joint frequency data should represent wind speeds and directions averaged over the longest possible time period since the exposure period used in the human health risk analysis is equivalent to the average life span of an individual. However, for acute releases, such as would result from accidents, the data should be

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representative of a 1-year release since a 1-year constant release was assumed for acute release scenarios. The uncertainty of the joint frequency data is therefore a function of the variability of the wind on an annual basis and of how many years of data were used to estimate the average annual wind conditions.

To estimate the uncertainty in Chi/Q caused by the variations in atmospheric conditions, one site was chosen for which sufficient wind profile data were available to perform the analysis. (However, for a more complete uncertainty analysis, every site would have to be analyzed individually since the method for obtaining the data, the instrumentation used, the location of the meteorological tower relative to the facility, and the number of samples taken vary from installation to installation.) The meteorological data at the ORNL–East Tower were used since the data are readily available, fairly extensive, and measurement uncertainties are negligibly small compared to wind condition variability. The meteorological data are taken each hour, with measurement uncertainties of one degree for wind directions and 0.1 mph for wind speeds. Since GENII uses 16 wind directions of 22.5 degrees per directional sector, a 1-degree uncertainty in wind direction would have a negligible effect on the wind velocity profiles used for modeling (these profiles present wind velocity as a function of direction, by degree). GENII also uses only six wind speed ranges separated by approximately 2 mph and only seven stability classes. Therefore, wind speed uncertainties of 0.1 mph are negligible relative to model input capabilities for both mean wind speeds and stability classes.

The only uncertainty that must be considered is the representativeness of the joint frequency data to the "actual" conditions one would experience during exposure. To estimate this uncertainty for one site, the hourly data taken at the ORNL–East Tower were averaged over 1 year to produce one joint frequency data set for that year. Since data have been acquired since 1987, seven yearly data sets could then be constructed (1987–1993). The GENII code was run for each of these joint frequency data sets to determine a Chi/Q with all other parameters being constant. The results presented in Table D.4–1 show that the standard deviation for Chi/Q for this set of data is 1.27E-12. Two standard deviations are typically used to bound data within the 95% confidence level. Using two standard deviations, the uncertainty of the resultant Chi/Q is approximately $\pm 10\%$. Therefore, the joint frequency data averaged over 7 years would also be expected to have an uncertainty of no more than $\pm 10\%$.

Table D.4-1. Descriptive Statistics for Chi/Q from ORR Meteorological Data

Statistic	Value
Mean	2.34E-11
Standard deviation	1.27E-12
Two standard deviations	2.54E-12 (10% of mean value)

Shor et al. (1982) (the source of the agricultural yield data) report that the margin of error for the agricultural yields is ±10%; the distribution had to be determined from the data in that study. From evaluating various yields from counties surrounding SRS, it was determined that a normal distribution was appropriate for the crop yields.

After the range and distribution of the input parameters were established, 300 input data sets were developed using the Latin Hypercube sampling technique. The regression analysis was then performed on the 300 model outputs. The coefficients resulting from the regression analysis and the probability of a coefficient being zero from the test of the null hypothesis are presented in Table D.4-2.

Table D.4–2. Results of GENII Sensitivity Study

Variable	Coefficient	Probability
Chi/Q	113,787.87	0.000
Yield Rate—Grain for Human Consumption	326.36	0.00
Yield Rate—Fresh Forage for Beef Cattle	202.11	0.05
Beef Dietary Fraction for Stored Feed	100.51	0.17
Yield Rate—Stored Feed for Milk Cows	74.28	0.09
Yield Rate—Stored Feed for Poultry	31.17	0.73
Yield Rate—Root Vegetables	27.57	0.62
Yield Rate—Stored Feed for Beef Cattle	25.37	0.56
Yield Rate—Leafy Vegetables	-6.58	0.68
Yield Rate—Fruit	-18.43	0.45
Yield Rate—Fresh Forage for Milk Cows	-32.35	0.75
Milk Dietary Fraction for Stored Feed	-42.69	0.56
Yield Rate—Stored Feed for Laying Hens	-102.27	0.25

Of all the variables considered in the analysis, only Chi/Q, the yield of grain for human consumption, and the yield of fresh forage for beef cattle were below the 0.05 probability level of having a zero coefficient. This means that the AEDE was most sensitive to variations in these three variables. Latin Hypercube sampling and regression analysis were performed again using these three variables only. The resulting partial correlations (which indicate the strength of the linear dependence of a parameter and factor out the first-order correlations between input variables) are presented in Table D.4–3.

Table D.4–3. Correlation Coefficients for Significant Variables

Variable	Partial Correlation
Chi/Q	0.99
Yield Rate—Grain for Human Consumption	0.17
Yield Rate—Fresh Foliage for Beef Cattle	0.12

Table D.4–3 reveals that the most sensitive variable was Chi/Q with a correlation coefficient of 0.99. This means that the uncertainty in Chi/Q will probably affect the uncertainties in risk much more than the uncertainties in the other two parameters. This is similar to the results found in an uncertainty study

by Lyon et al. (1992), in which the Chi/Q correlation coefficient was 0.95. Despite the small contributions from the other two variables (grain yield for humans and fresh forage yield for beef cattle), the uncertainty analysis was performed using all three variables to ensure the thoroughness of the analysis.

D.4.1.1.2 *Uncertainty Analysis*

The uncertainty analysis was performed using the GENII-S code again, along with the three parameters shown in Table D.4-3. The results presented in Table D.4-4 show that the deviations in AEDE were ±9%. This is nearly the same uncertainty as that of Chi/Q (which, the reader will recall from preceding discussion, was ±10%); this is as expected, since the correlation coefficient of Chi/Q is 0.99.

Table D.4-4. Descriptive Statistics for AEDE from the Uncertainty Analysis

Statistic	Value
Mean	2.5E+4
Deviation (Max-Mean)	2.15E+3 (9% of mean value)

D.4.1.2 Hazardous Chemicals

The ISC2 code (EPA, 1992) was used in the PEIS to estimate atmospheric fate and transport of hazardous chemicals. ISC2 estimates unit air concentrations 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, similar to the Chi/Q calculation in GENII. Because of the simplicity of the approach in ISC2, the Chi/Q, cancer potency factors, and RfDs are the only parameters used in modeling, and all are sensitive parameters on risk. However, recall from Section D.4.1 that the uncertainties in cancer potency factors and RfDs were not considered applicable in the PEIS uncertainty analysis since only relative, not absolute, uncertainties were being sought. Therefore, Chi/Q was the only sensitive variable in the ISC2 model for the purposes of this uncertainty analysis. Since the calculation for Chi/Q in ISC2 is almost identical to that in GENII, the uncertainties in Chi/Q are ±10%.

D.4.1.3 Conclusion for Treatment and Storage Sites

The relative uncertainty of risk for the PEIS for comparison purposes could not be determined since the uncertainties in source terms were not available for this analysis. For the parameters pertaining to ingestion or inhalation, including Chi/Q, crop yields, and dietary fractions of humans and animals, the only significant parameter was Chi/Q, which had an uncertainty of $\pm 10\%$.

Because the uncertainties for parameters other than the source term are relatively low, the overall risk uncertainties should be of approximately the same order of magnitude as the source term uncertainties determined by ANL.

If the critically exposed population in the PEIS is relatively small, the uncertainties in the breathing rates of humans, dose conversion factors, risk factors, and RfDs become significant, and the uncertainties in risk increase accordingly.

D.4.2 Disposal Sites

Groundwater transport was considered the only significant environmental transport pathway for disposal sites. Three computer codes were used to estimate disposal risks. The DUST code (Sullivan, 1992) was used to estimate the amount leached from the disposal site; MEPAS (Droppo et al., 1989) was used to calculate fate and transport of the contaminants; and the DITTY portion of the GENII code (Napier et al., 1988) was used for the ingestion and exposure assessment. The uncertainty in these disposal risk calculations was estimated based on a sensitivity and uncertainty analysis of the MEPAS code conducted in April 1992 by ORNL and PNL (Lyon et al., 1992).

The applicability of the sensitivity and uncertainty analysis of the MEPAS code to the PEIS was evaluated. The locations studied by Lyon et al. were chosen to encompass high-risk sites (sites for which population fatalities were estimated at greater than 1), medium-risk sites (where population fatalities were predicted to range between 1 and 0.0001), and low-risk sites (with population fatalities estimated at less than 0.0001). Of the six contaminated sites studied, four involved the groundwater pathway. These four were ORNL Waste Area Grouping 6, the Hanford Nonradioactive Dangerous Waste Landfill Site, LLNL Site 300 Landfill 6, and FEMP Operable Unit 1. Because these four sites are located

at four installations that were included in the PEIS health risk analyses, the results from the 1992 study were considered applicable to the PEIS.

Before relating the results of the study by Lyon et al. to the PEIS results, two differences must be pointed out. First, the PEIS used the DUST model instead of MEPAS to input the rate of contaminant release from the disposal site; however, the methodology used in the PEIS was identical to that used in the MEPAS study by Lyon et al. Second, the risk estimates in the study by Lyon et al. were time-weighted such that health effects that occurred sooner were weighted more heavily than those occurring later; the PEIS risks were not time-weighted. However, the contaminants in the Lyon study—uranium-238, strontium-90, benzene, and trichloroethene—moved through the groundwater at relatively similar rates and relatively fast; therefore, time-weighting the results would have a neglible effect on the uncertainties. Moreover, these contaminants are some of the primary constituents in the PEIS source terms. Because of these factors, the variations in risk estimates determined by Lyon et al. should provide a reasonable estimate of the uncertainties in the PEIS.

Latin Hypercube sampling was used to perform the sensitivity and uncertainty studies. The sensitivity analysis was performed by PNL, which used the time-weighted number of health effects as the dependent variable. The initial sensitivity rankings of the inputs were based on the partial correlation coefficients (indicating the strength of the linear dependence of the parameters). Typically, only three to six parameters showed sufficient sensitivity to be considered for the uncertainty analysis at the various sites. The null hypothesis that a coefficient was zero was tested to the 95% confidence level (i.e., parameters were considered sufficiently sensitive if there was a probability of 0.05 or less that a parameter's coefficient in the regression equation was zero).

Table D.4-5 presents the input parameters with significant correlation coefficients and the number of orders of magnitude difference between the 95th percentile upper and lower confidence levels. The significant parameters are listed in order of the highest to lowest correlation coefficients. The authors concluded that the most vital components of the risk characterization process are the initial concentrations of contaminants, contaminant inventories, and contaminant flux rates at the site. In many cases, the final risk estimate is directly proportional to these values. Uncertainties in the subsurface partitioning coefficient, K_ds, were determined to be insignificant relative to these other components.

Table D.4–5 shows that the differences in population risk estimates between the upper and lower 95th-percentile confidence bands ranged from 0.2 to 12.2 orders of magnitude. Note that the uncertainty at Hanford was very high in relation to the other three sites (12 orders of magnitude compared to 0.2, 1.5, and 2.1). This was because of a large decrease in population risk from the lower 80th percentile to the lower 95th percentile, accounting for approximately 10 orders of magnitude of uncertainty; there is only a difference of 2.2 orders of magnitude of uncertainty between the upper 95th percentile to the lower 80th percentile. Excluding the lower 80th to 95th percentile of the uncertainty for Hanford from consideration (because this behavior appears to be unique to Hanford and is extremely uncharacteristic of the other sites), the most reasonable estimate of the uncertainty with respect to disposal risks in the PEIS would be between 1 and 2 orders of magnitude.

This uncertainty estimate does not take into account uncertainties in the waste inventories provided by ANL. If the uncertainties in the inventories are provided by ANL, the risk uncertainty estimated in the preceding paragraph can be adjusted accordingly.

D.4.2.1 Conclusion for Disposal Sites

The most reasonable estimate of the uncertainty in the risk predictions in the PEIS for the disposal sites was expected to be approximately one to two orders of magnitude, based on the study by Lyon et al. (1992). If ANL provides source term uncertainties in the future, the uncertainties in risk in the PEIS can be adjusted accordingly.

Table D.4-5. Uncertainties of Risk Predictions via the Groundwater Pathway

Site	Significant Parameters (from highest to lowest correlation coefficient)	Population Risk Orders of Magnitude Difference[a]
ORR—Waste Area Group 6	1) Contaminant inventory 2) Surface K_d 3) Subsurface K_d 4) Discharge rate of White Oak Lake into the Clinch River	1.5
Hanford—Nonradioactive Dangerous Waste Landfill Site	1) Thickness of saturated zone 2) Waste leaching rate 3) Transverse dispersivity in saturated zone 4) K_d in saturated zone 5) K_d in partially saturated zone 6) Population drinking contaminated groundwater	12
LLNL—Site 300 Landfill 6	1) Flux rate 2) Leaching rate 3) K_d in first partially saturated zone 4) K_d in second partially saturated zone 5) K_d in saturated zone 6) Population drinking contaminated groundwater	2.1
FEMP—Operable Unit 1	1) Contaminant inventory 2) Pore water velocity in saturated zone 3) K_d in first partially saturated zone 4) K_d in second partially saturated zone 5) K_d in saturated zone 6) Travel distance in saturated zone to receptor	0.2

[a] Orders of magnitude difference between the 95th percentile upper and lower confidence levels.

D.4.3 Waste Management Workers

The MicroShield code (Grove Engineering, Inc., 1992) was used to calculate external radiation exposure to waste management workers for the waste management portion of the PEIS. MicroShield is capable of performing sensitivity studies for the shield thickness, distance-from-source-to-shield, and distance-from-source-to-receptor parameters. Sensitivity studies on other parameters such as material density and source strength must be performed manually.

For the comparison of PEIS alternatives, only the parameters that cause relative error, not absolute error, are the ones desired in determining the risk uncertainties. Since the PEIS treatment facilities and operational equipment were hypothetical in nature and were all assumed to be identical for the various treatments required, many parameters could be excluded from this uncertainty study. These included the shielding material and thickness, and the distances of the shield and receptor from the source.

Uncertainties were introduced in the PEIS risk estimates from relating waste throughputs to source volumes (volumes of waste in treatment vessels) and unit dose methodologies. For the PEIS, the throughput of waste for each treatment module for each alternative was provided by ANL. Since MicroShield requires input of the source (or waste) volume rather than the waste throughput, regression equations were used to relate throughputs to treatment vessel volumes using known values for existing facilities, derived from facility data provided by Morrison Knudsen Corporation (1993, 1994). The treatment modules that have variable capacities included feed waste bins, shredders, evaporators, high pressure spray/blast booths, solidification units, aqueous tanks, neutralization tanks, ion exchange tanks, oxidation reactor tanks, incinerators, metal melters, thermal desorption units, mercury roasting kilns, metal deactivation units, lead melting tanks, soil washing tanks, sludge washing tanks, debris washing tanks, and polymer blending tanks. (The size of some modules, such as drum compactors, did not change since the drum sizes remain the same for various throughputs; only the number of drums changed.)

There were two sources of error in the worker exposure calculations. First, the known throughputs and volumes consisted of three or four sizes categorized as extra-small, small, medium, and large. Since only three or four sizes existed to derive the regression equations for each treatment module, the maximum error of the three or four known values was used, regardless of throughput.

The second source of error resulted from using the unit dose methodology, in which the unit dose to a worker is calculated based on exposure to 1 m^3 of waste in a 1-m^3 container. Since the capacity of some of the treatment modules varied, the unit doses had to be scaled to reflect the doses for the correct waste volumes in these cases. To derive this relationship, MicroShield was executed for each of the variable-size modules for a range of waste volumes, and a regression equation was used to relate the dose from the various waste volumes to the unit dose.

To estimate the uncertainty in risk predictions from these two sources of error, an alternative was chosen in which the treatment train consisted of throughputs and treatment modules for which larger errors on

the regression curves existed. The management of LLMW at INEL in Regionalized Alternative 3 was chosen. Since the throughput changed with each of the 57 treatment modules for this alternative, and the number of workers changed with throughput, the actual dose for each treatment module had to be determined. The total actual dose was then calculated in an EXCEL spreadsheet and compared to that in the PEIS, resulting in an approximate ±6% error.

The shielding materials used for the PEIS included air, concrete, iron, and water. Since the construction, operation, and maintenance of all the facilities were assumed to be identical because the facilities are hypothetical in nature, any variations in the densities of concrete, iron, or water that might occur would cause absolute errors in risk predictions but would not cause relative errors (the type of errors sought for comparison purposes). The only site-specific parameter that might cause relative error would be air density since it is a function of the altitude of the treatment site. Because the sea-level air density of 0.00122 g/cm^3 was used for all locations in the PEIS, the error would be the difference between the average density at a specific location and the density at sea level. The altitudes for the facility locations in the PEIS ranged from sea level to approximately 5,300 feet at RFETS in Golden, Colorado. Therefore, the corresponding air densities ranged from 0.00122 to 0.00127 g/cm^3. This variability would have little effect on the shielding properties of air, so its effect on risk estimates would be negligible.

D.4.3.1 Conclusion for Worker Risk

Variability in parameters such as shield thickness, the distance-from-source-to-shield, and distance-from-source-to-receptor would be the major source of absolute error in risk estimates. However, these parameters would not have contributed to *relative* error since they were hypothetical in nature and were assigned identical values at all facilities. Uncertainties in the source terms and waste throughputs are significant for alternative comparisons in the PEIS since they are site-specific parameters. However, as with the source terms for the treatment and storage sites and disposal sites, ANL had not provided the uncertainties in source terms for WM workers at the time of this study; therefore, uncertainties for worker risks could not be determined. Because the uncertainties for parameters, other than source term, that contribute to relative error are relatively low (±6%), the overall risk uncertainties should be approximately of the same order of magnitude as the source term uncertainties determined by ANL.

D.5 Models Used in the PEIS Human Health Risk Evaluation

The ORNL Center for Risk Management used a number of computer codes to generate the PEIS human health risk estimates; these included numerous in-house codes based on established outside models for application of the unit risk approach.

GENII (Generation II of the Hanford Environmental Radiation Dosimetry Software System) (Napier et al., 1988) was used to assess the exposures to the offsite and noninvolved populations resulting from atmospheric releases of radioactive contaminants during routine facility operations and accidents, and to assess the intruder's radiological exposure to contaminated soil.

GENII is the second generation of a model developed for DOE at PNL to incorporate internal dosimetry models recommended by the ICRP into Hanford's existing environmental pathway analysis models. GENII analyzes environmental contamination resulting from both acute and chronic radionuclide releases by calculating radiation doses to individuals or populations from inhalation, ingestion of contaminated food and water, and external exposure through soil, water, and air. The GENII codes were developed under a stringent quality assurance plan based on American National Standards Institute (ANSI) standard NQA-1 as implemented in the *PNL QA Manual* (PNL-MA-70). It includes the DITTY (Dose Integrated Over Ten Thousand Years) code, which was used to calculate doses to the hypothetical farm family in the disposal scenarios as described below.

GENII has been used worldwide by several hundred users. Some noted applications include the Hanford Defense Waste EIS, Hanford's annual reports, the Hanford Safety Analysis, the Reactor Retirement EIS for PNL, and the ANL New Production Reactor Study. It has also been accepted by the State of Washington.

EPA's ISC2 (Industrial Source Complex Dispersion Models, Version 2) (EPA, 1992) was used to model atmospheric exposure modeling to chemical contaminants for the offsite and noninvolved worker populations. The code was designed specifically to support the EPA's regulatory modeling programs, and has EPA approval.

The DUST (Disposal Unit Source Term), MEPAS (Multimedia Environmental Pollutant Assessment System), and DITTY models were used in series to estimate exposures to contaminated groundwater.

DUST was used to calculate the flux of contaminants released and transported to the disposal facility boundary; these fluxes were then used as the input to MEPAS. The transport portion of MEPAS was used for the vadose and saturated zone plume migration calculations; the output concentrations from MEPAS were then used as input to DITTY. The DITTY code was then used for dose assessment calculations.

DUST was developed at Brookhaven National Laboratory (BNL) (Sullivan, 1992). This code models the release and transport of radionuclides through a shallow land disposal facility. DUST contains models to predict fluid flow, container degradation, waste form leaching, and radionuclide transport. DUST is useful for screening to determine which radionuclide is released at the highest rate, and for parameter sensitivity analysis. It has been extensively tested and verified, and the code predictions have been compared to known analytical solutions and to other code predictions; several verification tests are provided in the *Data Input Guide* (Sullivan, 1992). An important application of DUST was the modeling of field lysimeter release data collected at ORNL and ANL over a 7-year period.

MEPAS (Droppo et al., 1989) was originally developed in 1986 by PNL to assist the DOE Office of Environmental Safety and Health in prioritizing sites for remedial activities. This model is an objective, physics-based, PC-platform system that uses mathematical algorithms and a pathway analysis to evaluate the release of contaminants into the environment; the movement of these contaminants through and between multiple environmental media; exposure to surrounding human populations via inhalation, ingestion, dermal contact, and external dose; and the human health effects due to exposure to both chemicals and radionuclides.

MEPAS has been the subject of numerous technical reviews and has been widely used. Applications include the identification and prioritization of areas of existing environmental problems and risk at DOE's defense production facilities, and the assessment of potential risks for a number of commercial clients, the Hanford Site Single-Shell Tank Waste Characterization Program, the Hanford grout studies of hazardous waste risks, and 20 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites.

DITTY was used in the PEIS analysis to calculate radiological doses to the hypothetical farm family. DITTY was developed to calculate long-term population exposures from waste disposal sites; the time frame for calculations in DITTY is 10,000 years, divided into 143 periods of 70 years each. DITTY

calculates the lifetime cumulative dose equivalent for each time period and the EDE for the period of maximum dose.

The risks due to chemicals for the intruder scenario and the surface water deposition study were estimated using an upgraded version of the PRESTO-II risk assessment code (Fields et al., 1986). PRESTO-II was developed at ORNL to assist EPA in assessing the potential human health impacts from the disposal of LLW. PRESTO-II, originally written for a mainframe computer, was based on methodologies presented in the U.S. Nuclear Regulatory Commission *Reg. Guide 1.109* (NRC, 1977) for the release, transport, uptake, and human health risk assessment of radionuclides released from a shallow land burial trench. The PRESTO-II code was downloaded to a PC and augmented with a windows interface; this version of the code is called PRESTO-W (Fields and Melescue, in preparation). Further code development included adding the capability to simulate near-field scenarios where the contaminant concentrations of the environmental media are known at the receptor location. PRESTO-W was also upgraded to estimate human health risks from chemicals. The chemical database in MEPAS was incorporated into PRESTO-W for initializing chemical properties, cancer slope factors, and RfDs. The hazard index and cancer risks from chemicals were calculated in PRESTO-W using the methodologies presented in the EPA Superfund risk assessment guidelines (EPA, 1989a).

The MicroShield 4 computer code (Grove Engineering, Inc., 1992) was used for assessing external radiation exposure to waste management workers. MicroShield 4 was developed for designing shields and containers, assessing radiation exposure to people and materials, making source strength calculations based on radiation measurements, and teaching shielding principles. This model uses a highly structured ANSI standard programming language with good numerical precision. Data for attenuation coefficients, buildup factors, and buildup factor coefficients are taken from information distributed by the Radiation Shielding Information Center and included in ANSI/ANS 6.4.3.

MicroShield is currently being used by 400 organizations worldwide. For example, MicroShield was used in assessments of the Chernobyl accident in the former Soviet Union (Grove Engineering, Inc., 1992) and of various commercial nuclear utilities. Numerous universities including Kansas State University, Pennsylvania State University, the Massachusetts Institute of Technology, the Georgia Institute of Technology, and Renesselaer Polytechnic Institute use MicroShield for teaching shielding principles.

INEXPLC is a QuickBASIC program designed by ORNL System Safety Engineering (Bloom, 1993). The code includes relatively simple models that simulate close-in (i.e., less than 50 m downwind from the

source) atmospheric dispersion, explosive releases, and particle deposition. These models are based on exact solutions to the differential equation of a convection, turbulent-diffusion model for a point source and a semicircular, finite-area source. In this model, it is assumed that simple gas dispersion takes place with no effects from nearby structures (building wake effects or downwash). The INEXPLC code was used in the WM PEIS worker risk analysis to estimate outdoor air concentrations from accidental chemical releases.

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WASTE MANAGEMENT
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT
for
Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste

Volume IV of IV

Appendix E Transportation
Appendix F Accidents
Appendix G Waste Minimization
Appendix H Technology Development
Appendix I Minority and Low-Income Population Distribution

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Appendix E

Radioactive and Hazardous Waste Transportation Risk Assessments

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Foreword

This appendix presents a summary of the transportation-related human-health risk assessment conducted for the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement (WM PEIS). It also provides references to more detailed sources of information for all waste types. The assessment of risks associated with the transportation of radioactive waste is described in Part I, the assessment for transportation of hazardous waste (HW) in Part II. The information presented in this appendix is supported by data in separate technical reports (Biwer et al., 1995; Lazaro et al., 1995b; Monette et al., 1995), that is, transportation technical memoranda, which describe the transportation for offsite and onsite shipments of radioactive and hazardous wastes.

Transportation of radioactive waste and HW presents a risk to both crew members and members of the public. Part of this risk results from the nature of transportation itself, independent of the radioactive or hazardous characteristics of the cargo (for example, increased levels of pollution from vehicular exhaust and accidents during transportation); these risks can be viewed as "vehicle-related" risks. In addition, transportation of radioactive waste or HW may pose additional risk because of the characteristics and potential hazards of the material itself; these risks are considered to be "cargo-related" risks.

For radioactive materials, the cargo-related impacts on human health during transportation are caused by exposure to ionizing radiation during routine (for example, incident-free) transportation and during accidents. During routine operations, the external radiation field must be below limits specified in Federal regulations. During transportation-related accidents, human exposures may occur following release and dispersal of radioactive materials via multiple environmental pathways such as exposure to contaminated ground or contaminated air, or ingestion of contaminated food.

In contrast to radioactive materials, hazardous chemicals do not pose cargo-related risks to humans during routine transportation-related operations. Waste transportation operations are generally well regulated with respect to packaging, such that small spills or seepages during routine transport are kept to a minimum and do not result in exposures (for example, containers of liquids are surrounded by absorbent overpacking). Potential cargo-related health risks to humans can occur only if the integrity of a container is compromised during an accident (that is, a container is breached). Under such

conditions, some toxic chemicals (such as chlorine gas) may cause an immediate health threat to exposed individuals.

In addition to acute health effects, cargo-related risk of excess cases of latent cancer from accidental chemical exposures has been estimated. The correlation of chemical dose with the induction of human cancer has traditionally been based on the linear/no-threshold hypothesis, similar to radioactive exposure. The treatment of carcinogenic effects of exposures resulting from accidental chemical releases has added uncertainty because the carcinogenic risk is estimated for short-term (1-hour) exposures. Lifetime risks less than 1 in 1 million have been considered negligible and are not estimated. The number of individuals experiencing an increased risk of cancer of 1 in 1 million or greater has been estimated, without attempting to estimate the precise risk for those in the category of greater than 1 in 1 million.

Health impacts from radioactive and hazardous materials are presented separately in Part I and Part II of this appendix. No attempt has been made (even in cases where both radioactive and hazardous components are present in the same materials) to add or compare the estimated risks for the two classes of contaminants. To understand and interpret the estimated health impacts presented in this appendix, readers must keep in mind the fundamental differences between radioactive and chemical contaminants discussed previously. The table on the following page summarizes the human health effects considered for the radioactive-waste and HW risk assessments in this appendix.

Endpoints Used for Human Health Effects: WM PEIS Transportation Risk Assessment[a]

Type of Human Health Effect	Nature of Health Effect	Radioactive Waste	HW
Vehicle-related effects: routine transportation			
Truck-emission-induced cancer fatality	Latent	✓	✓
Vehicle-related effects: accident			
Physical trauma fatality	Acute	✓	✓
Cargo-related effects: routine transportation			
Radiation-induced cancer fatality	Latent	✓	b
Radiation-induced cancer incidence	Latent	✓	b
Radiation-induced genetic effects	Latent	✓	b
Cargo-related effects: accident			
Potential life-threatening effects	Acute	c	✓
Potential for any adverse effects	Acute	c	✓
Cancer fatality	Latent	✓	d
Cancer incidence	Latent[e]	✓	✓
Genetic effects	Latent	✓	d

[a] Each check mark represents a quantitative measure of risk computed in this appendix. All end points are relevant to mixed waste because it contains both a radioactive and a hazardous component.

[b] No public exposure to the HW occurs during routine transportation.

[c] Threshold doses for radiological acute effects are generally in excess of 100 rem. Exposures from transportation-related activities (routine or accidents) have not been found to reach such a high dose level.

[d] Not applicable because of lack of scientific data to support the measure.

[e] For radioactive waste, the risk of cancer is expressed as the number of excess cases of cancer in the general population. For HW, the risk of cancer is expressed as the number of individuals in the general population experiencing an excess lifetime cancer risk of 1 in 1 million or greater.

Acronyms and Abbreviations

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

Acronyms

ALOHA™	Areal Locations of Hazardous Atmospheres
ANL-E	Argonne National Laboratory-East
ANL-W	Argonne National Laboratory-West
Bettis	Bettis Atomic Power Laboratory
BNL	Brookhaven National Laboratory
CFR	Code of Federal Regulations
CH	contact-handled
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
ER	environmental restoration
FEMP	Fernald Environmental Management Project
Fermi	Fermi National Accelerator Laboratory
FY	fiscal year
GTCC LLW	Greater-Than-Class-C low-level waste
HLW	high-level waste
Hanford	Hanford Site
HaWRAM	Hazardous Waste Risk Assessment Modeling
HQ	hazard quotient
HW	hazardous waste
ICRC	increased cancer risk concentration
INEL	Idaho National Engineering Laboratory
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LC_{50}	lethal concentration causing death in 50 percent of animals tested
LC_{LO}	lowest reported lethal concentration
LDR	land disposal restriction
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MEI	maximally exposed individual
Mound	Mound Plant
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
ORR	Oak Ridge Reservation
PAEC	potential adverse effect concentration
Pantex	Pantex Plant
PEIS	Programmatic Environmental Impact Statement
PGDP	Paducah Gaseous Diffusion Plant
PIH	poison inhalation hazard

PLC	potential life-threatening concentration
PORTS	Portsmouth Gaseous Diffusion Plant
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RFETS	Rocky Flats Environmental Technology Site
RH	remote-handled
SFEIS	Supplemental Final Environmental Impact Statement
SMAC	Shipment Mobility/Accountability Collection
SNL-NM	Sandia National Laboratories (New Mexico)
SNL-CA	Sandia National Laboratories (California)
SRS	Savannah River Site
TC_{LO}	lowest toxic concentration (lowest concentration causing any adverse effect)
TRUW	transuranic waste
TSCA	Toxic Substance Control Act
TSD	treatment, storage, and disposal
WAC	waste acceptance criteria
WIPP	Waste Isolation Pilot Plant
WM	waste management
WVDP	West Valley Demonstration Project

Abbreviations

°C	degree(s) Celsius
d	day(s)
°F	degree(s) Fahrenheit
ft	foot (feet)
gal	gallon(s)
h	hour(s)
kg	kilogram(s)
km	kilometer(s)
km^2	square kilometer(s)
L	liter(s)
lb	pound(s)
m	meter(s)
m^3	cubic meter(s)
mi	miles(s)
mi^2	square mile(s)
min	minute(s)
mrem	millirem
ppm	part(s) per million
rem	roentgen equivalent man
s	second(s)
yd^3	cubic yard(s)
yr	year(s)

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APPENDIX E—PART I:
Radioactive Waste Transportation Risk Assessment

E.1 Introduction

Transportation is an integral component of the Alternatives being considered for each type of radioactive waste in the U.S. Department of Energy (DOE) Waste Management Programmatic Environmental Impact Statement (WM PEIS). The types of radioactive waste considered in Part I are high-level waste (HLW), low-level waste (LLW), transuranic waste (TRUW), and low-level mixed waste (LLMW). For some Alternatives, radioactive waste would be shipped among the DOE Sites at various stages of the treatment, storage, and disposal (TSD) process. The magnitude of the transportation-related activities varies with each Alternative, ranging from minimal transportation for decentralized approaches to significant transportation for some centralized approaches. The human health risks associated with transporting various waste materials were assessed to ensure a complete appraisal of the impacts of each PEIS Alternative being considered.

This section provides an overview of the approach used in the PEIS to assess human health risks that may result from transporting radioactive waste. The assessment's scope, computer models used, important assumptions for each waste type, and methods for determining potential routes for transportation are discussed. The risk assessment results are summarized for all Alternatives for each waste type. In addition, to aid in understanding and interpreting the results, specific areas of uncertainty are described, emphasizing how the uncertainties may affect comparisons of the Alternatives. Finally, possible mitigative measures that could be implemented to reduce potential impacts are discussed.

The methods and assumptions used in the transportation-related radiological risk assessment were selected to ensure meaningful comparisons among programmatic-level Alternatives. Therefore, this assessment uses a number of generic assumptions appropriate to the programmatic nature of the PEIS; for example, because a detailed consideration of every possible waste shipment would be impractical, representative physical and radiological characteristics were determined for each waste type. Similarly, transportation routes were selected to be consistent with current practice and applicable regulations, but they may not be the actual routes that will be used in the future. Any specific actions for transporting radioactive wastes would be supported by the appropriate project-level environmental analyses and documentation.

Extensive studies of transportation risk assessment have been conducted for specific Federal actions (NRC, 1977a; DOE, 1986a; DOE, 1990a). However, care must be exercised when comparing the results of this PEIS transportation-related risk assessment with others. Although some Alternatives in this PEIS may be similar to those analyzed in other studies, the results of other transportation risk assessments may differ for many reasons. In general, the other studies did not consider the range of programmatic Alternatives being considered in this PEIS. Moreover, the other studies used assumptions and parameters specific to the actions being considered, which are not necessarily appropriate for this PEIS. In addition, revised radiation health risk conversion factors have recently been recommended (ICRP, 1991), and data on the projected waste inventory and on waste characterization have been revised and updated. Results of this PEIS are not intended to replace results of previous transportation risk assessments for ongoing or planned actions.

This section of the appendix should be read in conjunction with the technical reports describing the development of site-specific data on the waste inventory and characterization for each waste type (Folga et al., 1995; Goyette, 1995; Hong et al., 1995; Lazaro et al., 1995; Wilkins et al., 1995). Data on site-specific waste characterization are used for the transportation accident risk assessment but are not presented explicitly in this appendix. Similarly, the Alternatives analyzed for each waste type are only summarized in Part I; detailed Alternative definitions for each waste type are provided in the respective chapters of the PEIS for the waste type. The supporting technical reports prepared for each waste type contain detailed information on waste characterization, Alternative definitions, and risk assessment results (Monette et al., 1995a–d; Biwer et al., 1995).

E.2 Scope of Assessment

The scope of the PEIS transportation radiological risk assessment—including the Alternatives, transportation-related activities, potential vehicle- and cargo-related impacts, receptors, and transportation modes considered—is described in this section. Additional details of the assessment are provided in the sections that follow.

E.2.1 Onsite Versus Offsite Transportation

The transportation risk assessment includes the onsite and offsite transportation of radioactive waste. Onsite transportation involves transporting waste between facilities within a DOE Site's boundaries.

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Transfers of waste within a specific facility are not considered onsite shipments but are considered part of the normal facility operations. Offsite transportation refers to transporting waste between distinct Sites, including parts of the routes that may be within the boundaries of the origin and destination Sites.

Offsite transportation usually involves a radioactive waste shipment moving through a constantly changing landscape and potentially stopping at any place along a route. To effectively describe this situation, models that use simplified assumptions and generalizations are used to estimate risk from offsite shipments. National average or typical values are chosen for variables such as road and track dimensions, vehicular speed, traffic density, weather conditions, and stop times; population densities are modeled as being uniformly distributed. Conversely, onsite transportation occurs at a fixed location, which allows for a site-specific analysis. The onsite risk assessment uses site-specific characteristics, such as local weather, nonuniform distributions of population, and data on agricultural productivity.

The human health risks associated with onsite transportation are generally much smaller than those from offsite transportation, largely because of the limited distances for onsite shipment, limited population densities along the routes, and limited average travel speeds (DOE, 1992c). Accordingly, the impacts of onsite transportation are not likely to contribute significantly to differences among the Alternatives being considered. Therefore, for purposes of the PEIS, the onsite risk assessment has been limited to one representative Site—the Hanford Site (Hanford). This Site was selected primarily because it is relatively large and conducts activities for managing all waste types. The impacts calculated for the Hanford Site are believed to be typical of other large DOE Sites and conservatively estimate the impacts expected for smaller Sites. The risk assessment conducted for onsite transportation is intended to estimate the magnitude of potential risk for comparison with the risks of offsite transportation. The risk assessment also characterizes the typical site-specific transportation scenarios and impacts not encompassed in the offsite analysis.

E.2.2 Waste Type-Specific Alternatives

The transportation risk assessment conducted for the PEIS estimates the human health risks associated with transporting radioactive waste for a large number of Alternatives. In general, the PEIS Alternatives are considered independently for each waste type and reflect decentralized, regionalized, and centralized approaches. For each waste type, several options, referred to as "cases," have been

defined for each broad Alternative. The individual cases differ in the numbers, locations, and types of TSD facilities being considered.

For the offsite transportation risk assessment, each specific case is defined as a set of pairs (origin and destination) representing shipping linkages among generator, treatment, and disposal sites. The number of origin-and-destination pairs varies among cases, ranging from a small number of pairs for decentralized cases to many pairs for centralized ones. Examples of the linkages for shipment in two sample cases are shown in Figures E-1 and E-2. Figure E-1 represents a decentralized LLW case involving 12 disposal Sites. The Sites that would not have the capability for disposal ship their wastes to a Site that does. Figure E-2 represents a LLW centralized disposal case in which all Sites would dispose of their wastes at a single Site. Chapter 3 of the PEIS contains detailed descriptions of the Alternatives for each waste type. The Alternatives are summarized in the following paragraphs.

E.2.2.1 Alternatives for HLW

The generation, treatment, and management of HLW and the cases considered in the PEIS are described in detail in the HLW technical report (Folga et al., 1995). In summary, canisters of vitrified HLW would be produced at the four DOE Sites that have historically generated and currently store HLW and would be transported to a geologic repository for final disposal.

The analysis of HLW investigates storage options under the No Action, Decentralized, Regionalized, and Centralized Alternatives. For each of the latter three Alternatives, two cases are analyzed. The first assumes the repository will open as scheduled in 2015, while the second case assumes the repository opens after 2015. The cases differ primarily in the location of interim canister storage before final disposal in a repository. For assessing the impacts of transportation, this PEIS assumes the repository to be located at the candidate site of Yucca Mountain in Nevada, which is the only site authorized by legislation for investigation. The Alternatives are defined in Chapter 3 of the PEIS and are summarized as follows:

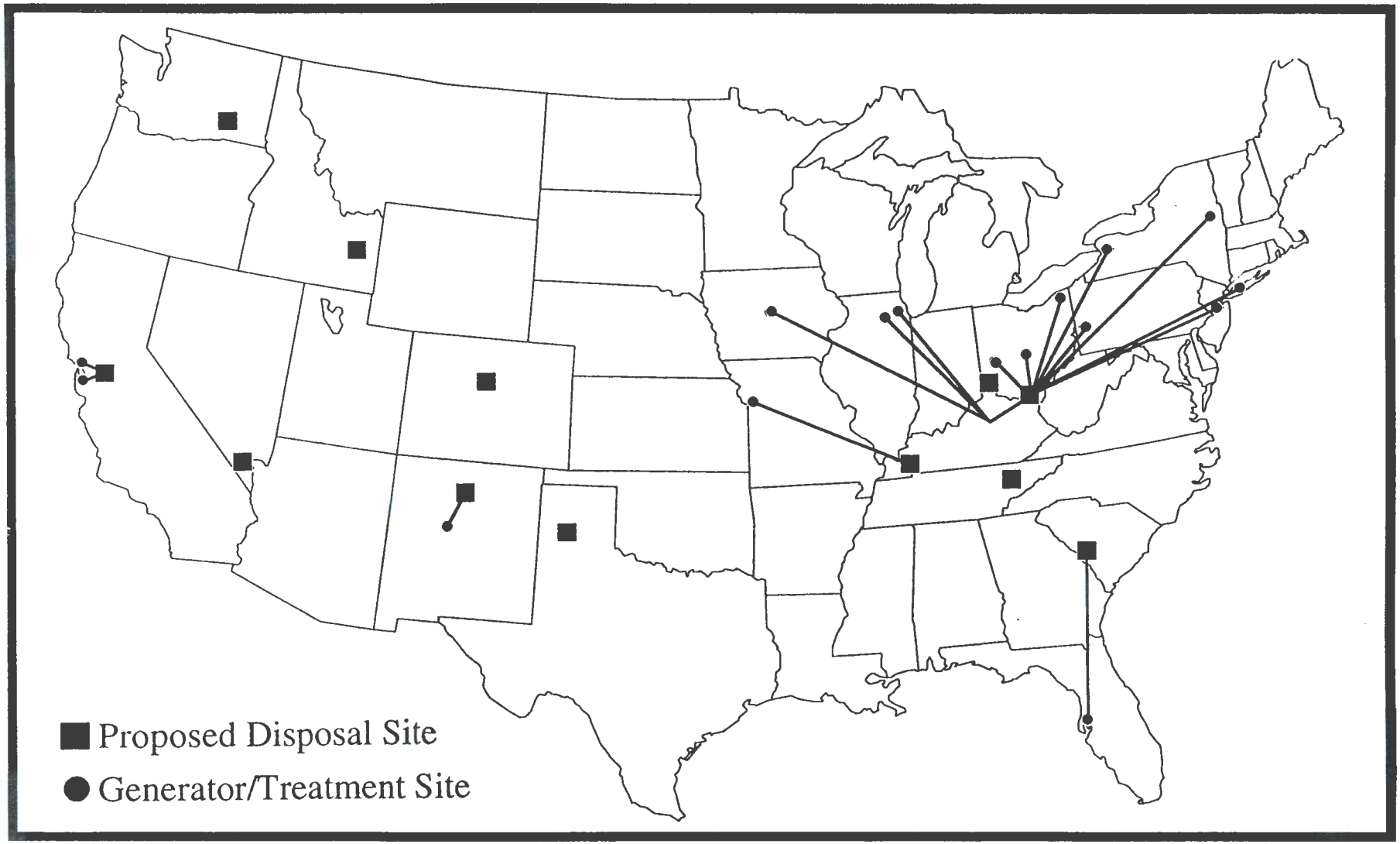

Figure E–1. Example of Shipping Linkages Among Generator, Treatment, and Disposal Sites for a LLW Decentralized Alternative.

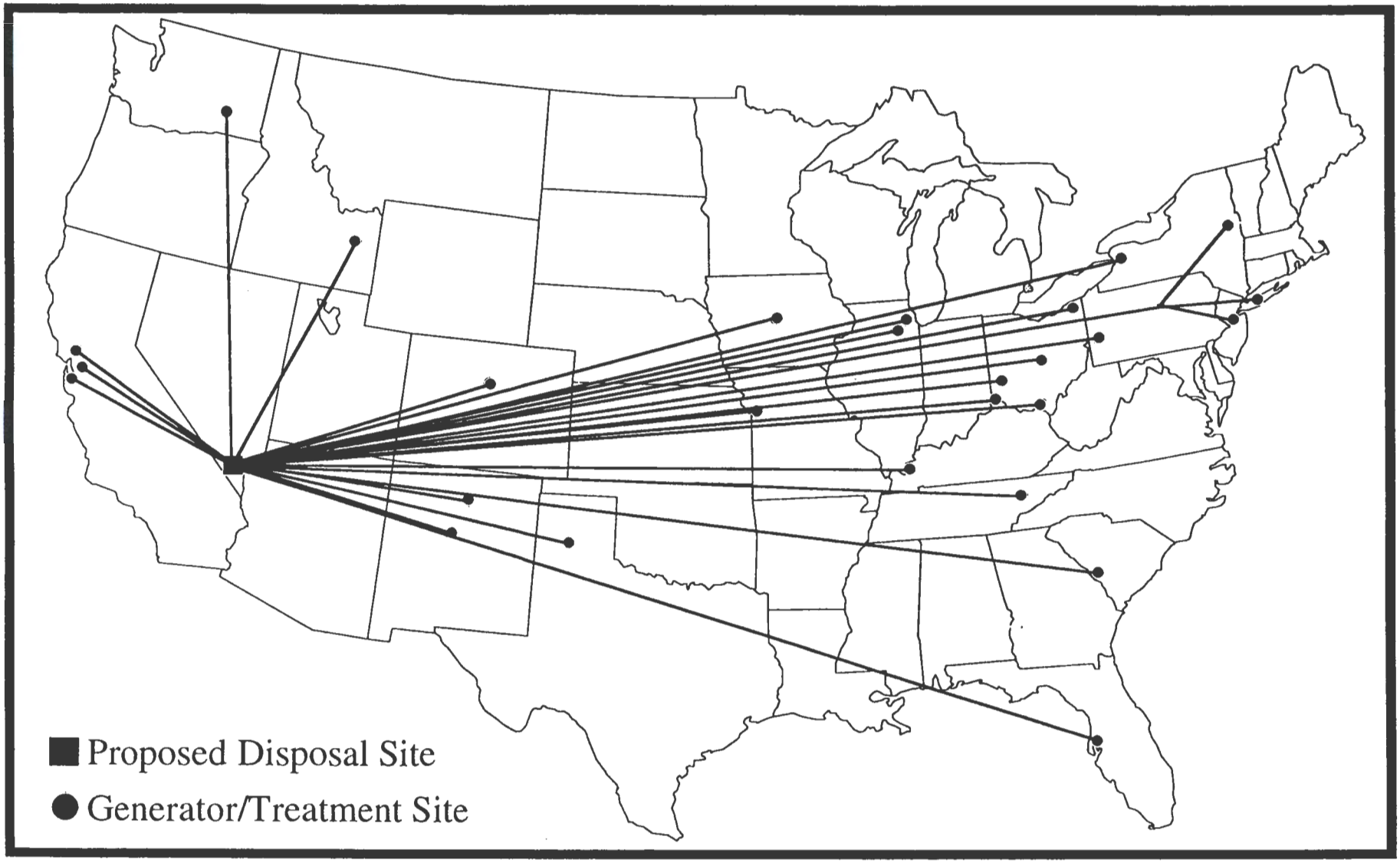

Figure E–2. Example of Shipping Linkages Among Generator, Treatment, and Disposal Sites for a LLW Centralized Alternative.

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- *No Action.* Store HLW canisters on an interim basis at Hanford, the Savannah River Site (SRS), and the West Valley Demonstration Project (WVDP) in existing and approved interim storage facilities until acceptance of HLW canisters at a geologic repository. Store HLW at Idaho National Engineering Laboratory (INEL) in bin-sets as calcine or in tank farms as liquid HLW.
- *Decentralized.* Provide adequate interim HLW canister storage capacity at each of the four sites that would produce HLW canisters until acceptance of HLW canisters at a geologic repository.
- *Regionalized 1.* Transport HLW canisters from WVDP to SRS and provide adequate interim storage capacity for HLW canisters at Hanford, SRS, and INEL until acceptance of HLW canisters at a geologic repository.
- *Regionalized 2.* Transport the HLW canisters from WVDP to Hanford and provide adequate interim storage capacity for HLW canisters at Hanford, SRS, and INEL until acceptance of HLW canisters at a geologic repository.
- *Centralized.* Transport the HLW canisters from the WVDP, INEL and SRS to Hanford and provide adequate interim storage capacity for HLW canisters at Hanford until acceptance of HLW canisters at a geologic repository. Case 1 assumes the repository opens on time in the year 2015. Case 2 assumes the repository opens later and all HLW is stored temporarily at Hanford.

E.2.2.2 Alternatives for LLW

Transportation risks have been calculated for 14 LLW cases. The cases range from decentralized to centralized approaches to TSD. Case 1 represents the No Action Alternative. The number of disposal sites varies from 16 (decentralized disposal) to 1 (centralized disposal). Treatment options also vary from decentralized to centralized approaches. In general, Sites without treatment or disposal capability would ship to the nearest Site with such capability. The Alternatives are defined in Chapter 3 of the PEIS and are summarized as follows:

- *No Action (Case 1).* All Sites would treat LLW using existing, planned, and approved treatment facilities and dispose of LLW at the six current disposal Sites in accordance with current arrangements.
- *Decentralized (Case 2).* All Sites would minimally treat LLW, stabilizing fines and liquids, and dispose of LLW at 16 Sites (Argonne National Laboratory-East [ANL-E], Brookhaven National Laboratory [BNL], Fernald Environmental Management Project [FEMP], Hanford, INEL, Lawrence Livermore National Laboratory [LLNL], Los Alamos National Laboratory [LANL], the Nevada Test Site [NTS], Oak Ridge Reservation [ORR], Paducah Gaseous Diffusion Plant [PGDP], Pantex Plant [Pantex], Portsmouth Gaseous Diffusion Plant [PORTS], Rocky Flats Environmental Technology Site [RFETS], Sandia National Laboratory-New Mexico [SNL-NM], SRS, and WVDP.
- *Regionalized 1 (Case 3).* All Sites would minimally treat LLW, stabilizing fines and liquids, and dispose of LLW at 12 Sites (Hanford, INEL, NTS, LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS).
- *Regionalized 2 (Case 9).* Eleven Sites (Hanford, INEL, LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS) would incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all Sites would minimally treat other waste; disposal would occur at

12 Sites (Hanford, INEL, NTS, LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS).

- *Regionalized 3 (Case 4).* All Sites would minimally treat LLW, stabilizing fines and liquids, and dispose of LLW at the nearest of six Sites (Hanford, INEL, NTS, LANL, ORR, and SRS).
- *Regionalized 4 (Case 12).* Seven Sites (Hanford, INEL, LANL, ORR, PORTS, RFETS, and SRS) would incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all Sites would minimally treat other waste; disposal would occur at six Sites (Hanford, INEL, NTS, LANL, ORR, and SRS).
- *Regionalized 5 (Case 19).* Four Sites (Hanford, INEL, ORR, and SRS) would incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all Sites would minimally treat other waste; disposal would occur at six Sites (Hanford, INEL, NTS, LANL, ORR, and SRS).
- *Regionalized 6 (Case 5).* All Sites would minimally treat LLW, stabilizing fines and liquids, and dispose of LLW at the nearer of two Sites (Hanford and SRS).
- *Regionalized 7 (Case 6).* All Sites would minimally treat LLW, stabilizing fines and liquids, and dispose of LLW at the nearer of two Sites (NTS and SRS).
- *Centralized 1 (Case 7).* All Sites would minimally treat LLW, stabilizing fines and liquids, and dispose of LLW at one Site (Hanford).
- *Centralized 2 (Case 8).* All Sites would minimally treat LLW, stabilizing fines and liquids, and dispose of LLW at one Site (NTS).
- *Centralized 3 (Case 14).* Seven Sites (Hanford, INEL, LANL, ORR, SRS, PORTS, and RFETS) would incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all Sites would minimally treat other waste; disposal would occur at one Site (Hanford).
- *Centralized 4 (Case 14a).* Seven Sites (Hanford, INEL, LANL, ORR, SRS, PORTS, and RFETS) would incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all Sites would minimally treat other waste; disposal would occur at one Site (NTS).
- *Centralized 5 (Case 21).* One Site (Hanford) would incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all Sites would minimally treat other waste; disposal would occur at one Site (Hanford).

E.2.2.3 Alternatives for TRUW

Transportation risks have been calculated for six TRUW alternatives. Each Alternative is comprised of a case that deals with contact-handled TRUW (CH-TRUW) and a case that deals with remote-handled TRUW (RH-TRUW). The cases range from decentralized to centralized approaches to treatment and storage before final geologic disposal. In general, Sites without treatment capability ship to the nearest Site with such capability. The treatment options considered are (1) treatment that meets the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria (WAC); (2) treatment to reduce gas generation using shredding, grouting, and nonsteel containers, resulting in waste that exceeds current WIPP-WAC requirements but does not meet land disposal restrictions (LDRs); and, finally, (3) treatment to a level

that meets or exceeds LDR requirements. The transportation assessment assumes that all TRUW will ultimately be shipped to WIPP for disposal. The Alternatives are defined as follows:

- *No Action (CH-TRUW Case 1, RH-TRUW Case 10).* Continue storing CH-TRUW at ANL-E, Hanford, INEL, LANL, Lawrence Berkeley Laboratory (LBL), LLNL, Mound Plant (Mound), NTS, ORR, PGDP, RFETS, SNL, SRS, and WVDP in accordance with current practices. Storage of RH-TRUW would continue at ANL-E, Hanford, INEL, LANL, and ORR in accordance with current practices. No transportation of waste is assumed.
- *Decentralized (CH-TRUW Case 4, RH-TRUW Case 11).* Ten Sites (ANL-E, Hanford, INEL, LANL, LLNL, Mound, NTS, ORR, RFETS, and SRS) would treat CH-TRUW to meet the WIPP-WAC. Five Sites (ANL-E, Hanford, INEL, LANL, and ORR) would treat RH-TRUW to WIPP-WAC. All treated TRUW would be disposed at WIPP.
- *Regionalized 1 (CH-TRUW Case 5, RH-TRUW Case 14).* Five Sites (Hanford, INEL, LANL, RFETS, and SRS) would treat CH-TRUW to reduce gas generation. Two Sites (Hanford and ORR) treat RH-TRUW to reduce gas generation. All treated TRUW would be disposed at WIPP.
- *Regionalized 2 (CH-TRUW Case 6, RH-TRUW Case 15).* Five Sites (Hanford, INEL, LANL, RFETS, and SRS) would treat CH-TRUW to LDR levels. Two Sites (Hanford and ORR) treat RH-TRUW to LDR levels. All treated TRUW would be disposed at WIPP.
- *Regionalized 3 (CH-TRUW Case 8, RH-TRUW Case 15).* Three Sites (Hanford, INEL, and SRS) would treat CH-TRUW to LDR levels. Two Sites (Hanford and ORR) treat RH-TRUW to LDR levels. All treated TRUW would be disposed at WIPP.
- *Centralized (CH-TRUW Case 9, RH-TRUW Case 15).* One Site (WIPP) would treat CH-TRUW to LDR levels. Two Sites (Hanford and ORR) treat RH-TRUW to LDR levels. All treated TRUW would be disposed at WIPP.

E.2.2.4 Alternatives for LLMW

Transportation risks have been calculated for seven LLMW Alternatives. The Alternatives range from decentralized to centralized approaches to TSD. The number of disposal Sites varies from 16 Sites to 1. Treatment options also vary from decentralized to centralized approaches. In general, Sites without treatment or disposal capability ship to the nearest Site with such capability. The Alternatives are defined in Chapter 3 of the PEIS and are summarized as follows:

- *No Action* (Case 1). Treatment and indefinite storage of LLMW generated in the future. No transportation occurs.
- *Decentralized (Case 2a).* Forty-nine sites treat LLMW to LDR levels, and 16 sites dispose.
- *Regionalized 1 (Case 4).* Eleven sites treat LLMW, and 12 sites dispose.
- *Regionalized 2 (Case 7).* Seven sites treat LLMW, and 6 sites dispose.
- *Regionalized 3 (Case 10a).* Seven sites treat LLMW, and 1 site disposes (NTS).
- *Regionalized 4 (Case 15).* Four sites treat LLMW, and 6 sites dispose.

- *Centralized (Case 17)*. One site treats LLMW (Hanford), and 1 site disposes (Hanford).

E.2.3 DESCRIPTION OF TRANSPORTATION ACTIVITIES

The transportation risk assessment determines transportation-related risks by considering the total amount of waste shipped over each route for each Alternative. The assessment considers waste currently stored or generated over the next 20 years. The assessment takes into account differences in the quantity and properties of wastes at each Site. In addition, characteristics of the routes between Sites are considered. For onsite transportation, most solid radioactive waste at the Hanford Site is assumed to be initially shipped to a central waste complex, regardless of possible offsite shipment for treatment or disposal. Therefore, the onsite transportation risks presented here apply equally to all Alternatives. The onsite assessment is not intended to be used as a basis for comparison among Alternatives.

The transportation risk assessment is limited to estimating the human health risks incurred during the actual transportation of waste for each Alternative. The risks to workers or to the public during the loading, unloading, and handling of waste before or after shipment are considered as part of normal facility operations and are not included in the transportation assessment. Similarly, the transportation risk assessment does not address how increased levels of transportation may affect local traffic flow, noise levels, logistics, or infrastructure.

E.2.4 CARGO-RELATED IMPACTS (RADIOLOGICAL)

The cargo-related impacts on human health during the transportation of radioactive materials would be caused by exposure to ionizing radiation. For all cases, radiological risks (risks resulting from the radioactive nature of the waste) are assessed for routine (normal) transportation and for accidents. The radiological risk associated with routine transportation results from the potential exposure of people to low levels of external radiation near a loaded shipment. The radiological risk from transportation-related accidents lies in the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of people through multiple exposure pathways, such as exposure to contaminated soil, inhalation, or the ingestion of contaminated food.

All radiologically related impacts are calculated in terms of committed dose and associated health effects in the exposed populations. The dose of radiation calculated is the total effective dose equivalent

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(Title 10, Part 20, of the *Code of Federal Regulations* [10 CFR 20]), which is the sum of the effective dose equivalent from exposure to external radiation and the 50-year committed effective dose equivalent (ICRP, 1977) from exposure to internal radiation. Doses of radiation are calculated in units of roentgen equivalent man (rem) for individuals and in units of person-rem for collective populations.

The potential exposures to the public from transporting radioactive materials, either from routine operations or from postulated accidents, are usually at such a low dose that the primary adverse health effect is the potential induction of latent cancers (that is, cancers that occur several years after the exposure). The correlation of radiation dose and human health effects for low doses has traditionally been based on what is called the "linear/no-threshold hypothesis," which has been described by various international authorities on protection against radiation. This hypothesis implies, in part, that even small doses of radiation have some cancer risk and that doubling the radiation dose means doubling the expected numbers of cancers. The types of cancer induced by radiation are similar to "naturally occurring" cancers and might be expressed at some point in the lifetime of the exposed individuals.

On the basis of the analyses presented in this appendix, transportation-related operations for all waste types are not expected to cause acute (short-term) radiation-induced fatalities or to produce immediately observable effects in exposed individuals. Acute radiation-induced fatalities occur at doses well in excess of 100 rem (ICRP, 1991), which generally would not occur for a wide range of transportation activities, including routine operations and accident conditions. (In general, individual acute whole-body doses in the range of 300 to 500 rem are expected to cause death in 50 percent of the exposed individuals within 30 to 60 days [ICRP, 1991].) For some severe accident scenarios analyzed, it is possible that doses to individuals would have short-term effects, such as temporary sterility and changes in blood chemistry; however, these effects cannot be readily quantified and therefore have not been assessed in this appendix.

The radiological impacts discussed in this appendix are expressed as health risks in terms of the number of estimated latent cancer fatalities, the incidence of cancer, and the genetic effects in exposed populations for each Alternative. The health risk conversion factors (expected latent health effects per dose absorbed) were derived from ICRP Publication 60 (ICRP, 1991).

E.2.5 VEHICLE-RELATED IMPACTS (NONRADIOLOGICAL)

In addition to the radiological risks posed by transportation-related activities, risks are also assessed for vehicle-related causes for the same routes for offsite transportation. These risks are independent of the radioactive nature of the cargo and would be incurred for similar shipments of any commodity. The vehicle-related risks are assessed for routine conditions and accidents. Vehicle-related risks during routine transportation are caused by potential exposure to increased vehicular exhaust emissions. The routine risks are primarily associated with travel in urban environments. The vehicle-related accident risk refers to the potential for transportation-related accidents that result in fatalities caused by physical trauma unrelated to the shipment's cargo. State-specific rates for transportation-related fatalities are used in the assessment. Vehicle-related risks are presented in terms of estimated fatalities for each Alternative.

E.2.6 TRANSPORTATION MODES

Although radioactive waste can be transported by various modes, all shipments have been assumed to take place either by truck or rail. For each Alternative, risks have been calculated separately for all truck and all rail options, although the actual shipping campaigns for a selected Alternative may involve a combination of the two modes. Rail shipments are assumed to take place by regular freight train; the use of special or dedicated rail service was not considered. Shipments by barge, though feasible for some Sites, have not been explicitly considered because this mode of transportation is somewhat limited and has not been established as a major programmatic option for the PEIS assessment. Similarly, shipments by aircraft and other modes were not considered.

The assumption that waste would be shipped entirely by truck or entirely by rail has been made for calculational purposes. All DOE Sites can ship waste by truck, but not all Sites have readily available rail access. A review of the transportation facilities at 35 major DOE Sites shows that 15 Sites have onsite rail access: 12 Sites have access within 16 kilometers (km) (10 miles [mi]), and the remaining Sites have access within 16 to 161 km (10 to 100 mi) of the Site (personal communication from Paul Johnson, Oak Ridge National Laboratory, to Fred A. Monette, ANL-E). To ship by rail, Sites that do not have direct rail access would likely ship waste by truck to the nearest rail siding, where the waste would be transferred to railcars. This type of shipment involving cargo transfer has not been considered in the risk assessment.

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E.2.7 RECEPTORS

Transportation-related risks are calculated and presented separately for workers and members of the general public. The workers considered are truck and rail crew members involved in the actual transportation of waste. The public includes all persons who could be exposed to a shipment while it is moving or stopped en route. Potential risks are estimated for the collective populations of exposed people, as well as for maximally exposed individuals (MEIs). The collective population risk is a measure of the radiological risk posed to society as a whole by the Alternative being considered. As such, the collective population risk is used as the primary means of comparing various Alternatives.

E.3 Packaging and Representative Shipment Configurations for Radioactive Waste

Regulations that govern the transportation of radioactive materials are designed to protect the public from the potential loss or dispersal of radioactive materials, as well as from routine doses of radiation during transit. The primary regulatory approach for ensuring safety is by specifying standards for the packaging of radioactive materials.

Because packaging represents the primary barrier between the radioactive material being transported and exposure of the public and the environment to radiation, packaging requirements are an important consideration for the transportation risk assessment. Regulatory packaging requirements and the representative packaging and shipment configurations assumed for each type of radioactive waste considered in the PEIS are described in this section. The information about shipment configuration includes truck and railcar payload capacities for each waste type.

E.3.1 PACKAGING

Although several Federal and State organizations are involved in regulating the transportation of radioactive waste, the U.S. Department of Transportation (DOT) and the U.S. Nuclear Regulatory Commission (NRC) have primary regulatory responsibility. In addition, DOE has formalized agreements with the NRC and DOT to delineate responsibilities of each agency. All transportation-related activities must be in accordance with applicable regulations of these agencies specified in 49 CFR 173 and 10 CFR 71.

Packaging for transporting radioactive materials must be designed, constructed, and maintained to ensure that they will contain and shield their contents during normal transportation. For more highly radioactive material, the packaging must contain and shield their contents in severe accidents. The type of packaging used is determined by the radioactive hazard associated with the packaged material. The basic types of packaging required by the applicable regulations are designated as Type A, Type B, or "strong and tight" (generally for low specific-activity material).

Type A packaging must withstand the conditions of normal transportation without the loss or dispersal of the radioactive contents. "Normal" transportation refers to all transportation conditions except those resulting from accidents or sabotage. Approval of Type A packaging is achieved by demonstrating that the packaging can withstand specified testing conditions intended to simulate normal transportation. Type A packaging, typically a 208-liter (L) (55-gallon [gal]) drum or standard waste box, is commonly used to transport wastes with low radioactivity levels. Type A packaging is routinely used in waste management for storage, transportation, and disposal. Type A packaging usually does not require special handling, packaging, or transportation equipment.

"Strong and tight" packagings may be used to transport certain low specific-activity materials (for example, mill tailings, uranium ore, natural uranium hexafluoride, and some LLW). Shipments of "strong and tight" packagings are excepted from certain packaging specifications and marking and labeling requirements but must still comply with many administrative controls. Functionally, "strong and tight" packagings are equivalent to Type A packaging because contents must not leak under normal transport conditions. Examples of "strong and tight" packages currently in use include steel drums, rectangular metal bins, and wooden boxes.

In addition to meeting the standards for Type A packaging, Type B packaging must provide a high degree of assurance that the package integrity will be maintained, even during severe accidents, with essentially no loss of the radioactive contents or serious impairment of the shielding capability. Type B packaging is required for shipping large quantities of radioactive material and must satisfy stringent testing criteria (specified in 10 CFR 71). The testing criteria were developed to simulate conditions of severe hypothetical accidents, including impact, puncture, fire, and immersion in water. The most widely recognized Type B packagings are the massive casks used for transporting highly radioactive spent nuclear fuel from nuclear power stations. Large-capacity cranes and mechanical lifting equipment are usually necessary for handling Type B packagings. Many Type B packagings are transported on trailers specifically designed for the package being used.

External radiation allowed to escape from a package must be below specified limits that minimize exposure of the handling personnel and the public. Most DOE waste shipments are handled only by the shipper and the receiver, an arrangement referred to as an "exclusive-use" shipment. For this type of shipment (regardless of the waste type or package), the dose rate for external radiation during normal transportation must be maintained below the following limits (49 CFR 173):

- Dose of 10 millirem per hour (mrem/h) at any point 2 meters (m) (6.6 feet [ft]) from the vertical planes projected by the outer lateral surfaces of the car or vehicle
- Dose of 2 mrem/h in any normally occupied position in the car or vehicle

Additional restrictions apply to radiation levels on the package surface; however, these restrictions do not affect the transportation-related radiological risk assessment. Representative external dose rates for each waste type are described in Section E.6.2.

For the purposes of risk assessment, specifying the actual package that will be used is unnecessary because all packagings of a certain type are designed to meet the same performance criteria; for instance, a 208-L (55-gal) drum and a standard waste box, each designed to meet Type A packaging criteria, would be expected to behave similarly under routine transportation and accident conditions.

E.3.2 Representative Packaging and Shipment Configurations by Waste Type

To conduct the transportation risk assessment, assumptions must be made about the types of packaging, the transporting vehicles, and the shipment capacities used for future waste shipments. Certain assumptions, such as types of vehicles and their legal weight restrictions, are common to all waste types; however, the radiological and physical characteristics of waste types differ, so separate packaging assumptions must be made for each. In all cases, waste is assumed to be characterized, treated, packaged, and labeled in accordance with applicable regulations before shipment.

E.3.2.1 Offsite Transportation

For all waste types, transportation is assumed to be in certified or certified-equivalent packagings, and exclusive-use vehicles are assumed to be used. Legal-weight heavy-haul combination (tractor-trailer) trucks are assumed to be used for highway transportation. Typically, Type A packages are transported

on common flatbed or covered trailers; Type B packages are generally shipped on trailers designed specifically for the packaging being used. For transportation by truck, the maximum payload weight is considered to be 19,958 kilograms (kg) (44,000 pounds [lb]), based on DOT highway weight limitations and an average tractor-trailer weight of 16,329 kg (36,000 lb).

Regular freight-train service is assumed for the rail transportation. The use of special or dedicated train service was not considered in the analysis. For rail transportation, average payload weights for boxcars range from 45,359 to 68,039 kg (100,000 to 150,000 lb). A median payload weight of 54,431 kg (120,000 lb) has been assumed for this assessment.

The above shipment capacities for truck and rail were assumed to be reasonable based on current practice. In reality, truck and rail shipment capacities vary from shipment to shipment at a given site, depending on the characteristics of the waste, operational practices, and site regulations. Because of the programmatic nature of the PEIS, representative shipment capacities were assumed for each waste type based on current practices. For truck shipments, payloads were taken to be near the regulatory weight limit because the density of most waste is such that volume tends not to be limiting, and it is common practice to load trucks near the legal weight limit for economical reasons. On the other hand, railcar capacities are seldom limited by the weight restrictions of the railcar and can vary over a wide range depending upon the density of the material. Therefore, a "median" railcar capacity of 120,000 lb was assumed for calculational purposes because railcar weights are not normally distributed. In addition, the total risk remains relatively unchanged if the size of each shipment is changed. If the maximum payloads are used, the number of shipments is minimized, resulting in the least number of potential accidents, although the consequences are higher. Conversely, smaller payloads require more shipments, resulting in more potential accidents, each of lessor consequence.

As discussed previously, the packaging type is determined primarily by radiological characteristics of the waste material. For the purposes of risk assessment, representative packagings have been determined for each type of radioactive waste on the basis of average waste characteristics and currently accepted practice. In practice, packagings are selected on a case-by-case basis and may differ from the representative types presented here. Assumptions about packaging and shipment are discussed in this section and are summarized in Table E–1.

Table E-1. Representative Packaging and Shipment Assumptions for Radioactive Waste Types

Waste	Packaging	Shipment Capacity[a]
HLW	Type B: similar to the defense HLW cask	Truck cask = 1 canister; rail cask = 5 canisters
LLW	Type A: 208-L (55-gal) drums or standard waste boxes or strong and tight packaging	Assumed to be limited by vehicular weight restrictions; payload capacity: truck = 19,958 kg (44,000 lb) and rail = 54,431 kg (120,000 lb)
TRUW	Type B	Assumed to be limited by package volume restrictions
	CH = TRUPACT-II	3 TRUPACT-IIs per truck and 6 per railcar; payload capacity: truck = 8.4 m^3 (11 yd^3) and rail = 16.8 m^3 (22 yd^3)
	RH = NuPac 72B	1 NuPac 72B per truck and 2 per railcar; payload capacity: truck = 0.89 m^3 (1.2 yd^3) and rail = 1.8 m^3 (2.4 yd^3)
LLMW	Type A: 208-L (55-gal) drums or standard waste boxes or strong and tight packaging	Similar to LLW

Notes: CH = contact-handled waste; RH = remote-handled waste.
[a] Truck shipments are assumed to be legal weight. Truck payload capacities were calculated by assuming a 36,287-kg (80,000-lb) gross vehicular weight limit and a tractor-trailer weight of 16,329 kg (36,000 lb). Rail shipments are by regular freight service. The median railcar payload capacity was taken to be 54,431 kg (120,000 lb).

E.3.2.1.1 *HLW Shipments*

Canisters of vitrified HLW are assumed to be shipped in a Type B package similar to the "defense HLW cask" being developed for SRS. The number of canisters to be transported in a cask differs for the truck and rail modes. The truck cask is assumed to accept one HLW canister, and rail capacity is assumed to be five canisters (DOE, 1987a). In the future, DOE will likely develop a multiple-canister HLW truck cask to minimize the number of shipments for major shipping campaigns; however, because a multiple-canister cask does not yet exist, impacts were calculated by assuming that a single-canister cask would be used. If a multiple-canister cask were designed and used in the future, risks would be significantly less than those in this analysis.

E.3.2.1.2 *LLW Shipments*

All LLW is assumed to be transported in strong and tight or Type A packaging, such as 208-L (55-gal) drums or standard waste boxes. Suitable Type A packagings are readily available from commercial sources. The number of shipments from a specific Site is calculated by projecting Site-specific information about waste inventory (weight) and limitations on shipment capacity for each transportation mode. The effects of potential waste treatment, such as volume reduction or incineration, are reflected in changes in waste density. All shipments are assumed to be at the maximum weight limits for truck and rail shipments. On the basis of typical LLW densities, roughly 80 drums with a 208-L (55-gal) capacity each would be shipped per truck, and 300 per railcar.

E.3.2.1.3 *TRUW Shipments*

The radiological characteristics of TRUW require the use of Type B packaging. The DOE has agreed to have the NRC certify the containers used for CH-TRUW and RH-TRUW shipments as meeting Type B specifications (DOE, 1990a). Shipments of TRUW will essentially consist of a number of Type A packages within reusable certified Type B packages. The Type B packages are assumed to be the TRUPACT-II for CH-TRUW and the NuPac 72B for RH-TRUW.

The TRUPACT-II was certified as meeting the NRC regulations for Type B packaging in August 1989 (DOE, 1990a). The container is a cylinder with a flat bottom and domed top that is transported in an upright position. Each TRUPACT-II is approximately 2.4 m (8 ft) in diameter and 3.1 m (10 ft) in height. The TRUPACT-II was designed to maximize payload in volume and in weight. The usable volume of each TRUPACT-II is approximately 2.8 cubic meters (m^3) (3.7 cubic yards [yd^3]). The payload capacity of each TRUPACT-II is 3,300 kg (7,275 lb). Three TRUPACT-IIs are assumed to be transported per truck, and six per railcar. The total number of required shipments has been calculated on the basis of waste volume, which is 8.4 m^3 (11 yd^3) for truck shipments and 16.8 m^3 (22 yd^3) for rail shipments.

The NuPac 72B shipping cask is assumed to be used for all RH-TRUW shipments. The NuPac 72B is being designed to meet Type B packaging specifications and is a scaled-down version of the certified NuPac 125B cask (DOE, 1990a). (The NuPac 125B was used to transport core debris from the damaged Three Mile Island nuclear power station to INEL.) The NuPac 72B cask is approximately

3.7 m (12 ft) long with a diameter of 1.1 m (3.5 ft). The usable volume of each NuPac 72B is approximately 0.89 m^3 (1.2 yd^3). The payload capacity of each NuPac 72B is limited to 3,629 kg (8,000 lb). One NuPac 72B is assumed to be transported per truck, and two per railcar. The total number of required shipments has been calculated on the basis of waste volume, which is 0.89 m^3 (1.2 yd^3) for truck shipments and 1.8 m^3 (2.4 yd^3) for rail shipments.

E.3.2.1.4 *LLMW Shipments*

Shipment of LLMW is assumed to be similar to LLW. Shipments of LLMW would meet any additional requirements for characterization and labeling associated with the HW component. In addition, shipments of liquid waste would meet regulatory requirements specified for liquids; that is, packages would contain adequate absorbent material to absorb twice the volume of the transported liquid, or a leak-tight overpack would be used (10 CFR 71).

E.3.2.2 Onsite Transportation

The policy at the Hanford Site is to use certified packaging whenever practicable for transporting radioactive materials onsite (Mercado et al., 1992). Therefore, the packaging used for onsite transportation is assumed to be the same as that used for offsite transportation. If an alternative means of packaging is necessary, a concept of equivalent safety is maintained while achieving the same shipping results. On site transportation safety is attained through such measures as limiting vehicular speeds, appropriate traffic controls, or increasing shielding for crew members and distance from the package.

In addition, the public has access to a number of routes on the Hanford Site. Unless such routes are barricaded while radioactive waste is being transported, shipments must meet all pertinent Federal regulations pertaining to public highways. Stringent procedures are followed at the Hanford Site to ensure the safety of workers and the public, providing the same level of safety for onsite and offsite shipments (WHC, 1993).

E.4 Analysis of Truck and Rail Routing

As discussed previously and illustrated in Figures E-1 and E-2, each case can be defined as a set of origin-and-destination pairs representing shipping linkages among generator, treatment, and disposal sites. The calculation of the transportation risk for an Alternative depends, in part, on the characteristics of the transportation routes between the origin and destination sites. Regulatory routing criteria and the methods used to determine representative truck and rail routes for the transportation risk assessment are described in this section.

E.4.1 Routing Regulations

The DOT routing regulations for public highways are prescribed in 49 CFR 177 (commonly referred to as HM-164). The objectives of the regulations are to reduce the impacts of transporting radioactive materials, to establish consistent and uniform requirements for route selection, and to identify the role of State and local governments in routing radioactive materials. The regulations attempt to reduce potential hazards by avoiding populous areas and by minimizing travel times. In addition, the regulations require that the carrier of radioactive materials ensure that the vehicle is operated on routes that minimize radiological risks, and that accident rates, transit times, population density and activity, time of day, and day of week are considered in determining risk.

A vehicle transporting a shipment of a "highway route controlled quantity" of radioactive materials is required by HM-164 to use the interstate highway system except when moving from origin to interstate or from interstate to destination, when making necessary repair or rest stops, or when emergency conditions make continued use of the interstate unsafe or impossible. Carriers are required to use interstate circumferential or bypass routes, if available, to avoid populous areas. Any State or Native American tribe may designate other "preferred highways" to replace or supplement the interstate system. Under its authority to regulate interstate transportation safety, DOT can prohibit State and local bans and restrictions as "undue restraint of interstate commerce." State or local bans can be preempted if inconsistent with HM-164.

The DOT has no railroad routing regulations specific to the transportation of radioactive materials. Routes are generally fixed by the location of rail lines, and urban areas cannot readily be bypassed.

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E.4.2 REPRESENTATIVE TRANSPORTATION ROUTES

E.4.2.1 Offsite Transportation

The scope of this PEIS assessment involves every DOE Site that generates, stores, or disposes radioactive waste. The transportation linkages among generator, treatment, and disposal sites depend on the type of waste and are defined explicitly for each case under consideration. For this PEIS, representative offsite truck and rail routes were determined for all possible pairs of origin and destination sites. Table E–2 gives the truck route distances between major DOE Sites, and Table E–3 gives the rail route distances. The routes were selected to be consistent with existing routing practices and all applicable routing regulations and guidelines; however, because the routes were determined for the purposes of risk assessment, they do not necessarily represent actual routes that would be used to transport waste in the future.

The representative truck routes were determined by using the routing model HIGHWAY 3.1 (Johnson et al., 1993a), and INTERLINE 5.0 was used to determine the rail routes (Johnson et al., 1993b). For truck and rail transportation, the route characteristics most important to the radiological risk assessment include the total shipping distance between each origin-and-destination pair and the fractions of travel in rural, suburban, and urban zones of population density. The route selected determines the total potentially exposed population along a route and the expected frequency of transportation-related accidents. Because of the large number of unique origin-and-destination pairs considered for the PEIS Alternatives, detailed route characteristics are provided in the technical reports prepared for each waste type (Monette et al., 1995a–d; Biwer et al., 1995).

E.4.2.1.1 *HIGHWAY 3.1*

The HIGHWAY 3.1 computer program is used for predicting highway routes for transporting radioactive materials by truck within the United States. The HIGHWAY database is a computerized road atlas that describes at least 386,243 km (240,000 mi) of roads. This database includes a complete description of the interstate highway system and of all U.S. highways. In addition, most principal State highways and many local and community highways are identified. The code is updated periodically to reflect current road conditions and has been compared with reported mileages and observations of commercial trucking firms.

Table E–2. Truck Route Distances (mi) Between Major DOE Sites[a]

	Ames	ANL-E	ANL-W	BCL	Bettis	BNL	Fermi	FBMP	Hanford	INEL	ITRI	KCP	KAPL-S	LBL	LLNL	LANL	Mound	NRF
Ames	0	351	1287	675	894	1206	341	611	1703	1287	1129	234	1163	1844	1853	1136	644	1287
ANL-E	351	0	1582	348	567	874	36	294	1998	1582	1333	520	831	2139	2148	1431	317	1582
ANL-W	1287	1582	0	1906	2125	2437	1572	1842	599	0	1177	1325	2393	963	972	1144	1875	0
BCL	675	348	1906	0	223	653	380	113	2322	1906	1463	650	626	2463	2472	1552	72	1906
Bettis	894	567	2125	223	0	506	599	312	2541	2125	1682	869	543	2682	2691	1771	291	2125
BNL	1206	874	2437	653	506	0	906	760	2853	2437	2113	1299	241	2994	3003	2201	721	2437
Fermi	341	36	1572	380	599	906	0	326	1975	1572	1359	519	863	2129	2138	1421	349	1572
FBMP	611	294	1842	113	312	760	326	0	2258	1842	1399	586	733	2399	2408	1488	49	1842
Hanford	1703	1998	599	2322	2541	2853	1975	2258	0	599	1593	1741	2809	875	894	1560	2291	599
INEL	1287	1582	0	1906	2125	2437	1572	1842	599	0	1177	1325	2393	963	972	1144	1875	0
ITRI	1129	1333	1177	1463	1682	2113	1359	1399	1593	1177	0	895	2085	1194	1154	111	1432	1177
KCP	234	520	1325	650	869	1299	519	586	1741	1325	895	0	1272	1881	1890	984	619	1325
KAPL-S	1163	831	2393	626	543	241	863	733	2809	2393	2085	1272	0	2950	2959	2174	694	2393
LBL	1844	2139	963	2463	2682	2994	2129	2399	875	963	1194	1881	2950	0	45	1274	2432	963
LLNL	1853	2148	972	2472	2691	3003	2138	2408	894	972	1154	1890	2959	45	0	1233	2441	972
LANL	1136	1431	1144	1552	1771	2201	1421	1488	1560	1144	111	984	2174	1274	1233	0	1521	1144
Mound	644	317	1875	72	291	721	349	49	2291	1875	1432	619	694	2432	2441	1521	0	1875
NRF	1287	1582	0	1906	2125	2437	1572	1842	599	0	1177	1325	2393	963	972	1144	1875	0
NTS	1520	1815	712	2078	2297	2670	1805	2014	1128	712	918	1428	2626	719	678	997	2047	712
ORISE	887	571	2077	399	586	808	603	299	2493	2077	1420	752	872	2592	2551	1509	335	2077
ORR	900	584	2048	412	563	821	616	312	2464	2048	1391	723	885	2563	2523	1480	348	2048
PGDP	629	385	1766	477	696	1115	417	409	2182	1766	1230	441	1099	2322	2327	1319	441	1766
Pantex	834	1038	1468	1168	1387	1817	1064	1104	1884	1468	313	600	1790	1485	1445	402	1137	1468
Pinellas	1481	1204	2617	1065	1252	1329	1236	965	3033	2617	1959	1293	1393	2945	2904	2048	1001	2617
PORTS	755	428	1986	84	265	689	460	173	2402	1986	1543	730	688	2543	2552	1632	152	1986
PPPL	1217	822	2448	546	398	189	854	635	2864	2448	2006	1192	291	3005	3014	2094	614	2448
RMI	751	419	1982	214	175	531	451	321	2398	1982	1673	860	416	2538	2547	1762	282	1982
RFETS	722	1017	716	1283	1500	1870	1005	1217	1132	716	483	631	1827	1283	1292	452	1250	716
SNL-NM	1120	1324	1168	1454	1673	2103	1350	1390	1584	1168	9	886	2076	1185	1145	102	1423	1168
SNL-CA	1853	2148	972	2472	2691	3003	2138	2408	894	972	1154	1890	2959	45	0	1233	2441	972
SRS	1175	892	2311	720	656	897	924	620	2727	2311	1653	987	961	2791	2750	1742	656	2311
SLAC	1885	2180	1004	2524	2723	3035	2167	2440	916	1004	1198	1939	2979	47	64	1294	2473	1004
WVDP	909	577	2140	372	257	492	609	479	2556	2140	1832	1018	314	2697	2706	1921	440	2140
WIPP	1301	1505	1759	1625	1813	2192	1531	1526	2175	1759	614	1067	2256	1509	1468	693	1561	1759
YM	1554	1849	746	2112	2331	2704	1839	2048	1162	746	952	1462	2660	753	712	1031	2081	746

Table E-2. Truck Route Distances (mi) Between Major DOE Sites[a]—Continued

	NTS	ORISE	ORR	PGDP	Pantex	Pinellas	PORTS	PPPL	RMI	RFETS	SNL-NM	SNL-CA	SRS	SLAC	WVDP	WIPP	YM
Ames	1520	887	900	629	834	1481	755	1217	751	722	1120	1853	1175	1885	909	1301	1554
ANL-E	1815	571	584	385	1038	1204	428	822	419	1017	1324	2148	892	2180	577	1505	1849
ANL-W	712	2077	2048	1766	1468	2617	1986	2448	1982	716	1168	972	2311	1004	2140	1759	746
BCL	2078	399	412	477	1168	1065	84	546	214	1283	1454	2472	720	2524	372	1625	2112
Bettis	2297	586	563	696	1387	1252	265	398	175	1500	1673	2691	656	2723	257	1813	2331
BNL	2670	808	821	1115	1817	1329	689	189	531	1870	2103	3003	897	3035	492	2192	2704
Fermi	1805	603	616	417	1064	1236	460	854	451	1005	1350	2138	924	2167	609	1531	1839
FEMP	2014	299	312	409	1104	965	173	635	321	1217	1390	2408	620	2440	479	1526	2048
Hanford	1128	2493	2464	2182	1884	3033	2402	2864	2398	1132	1584	894	2727	916	2556	2175	1162
INEL	712	2077	2048	1766	1468	2617	1986	2448	1982	716	1168	972	2311	1004	2140	1759	746
ITRI	918	1420	1391	1230	313	1959	1543	2006	1673	483	9	1154	1653	1198	1832	614	952
KCP	1428	752	723	441	600	1293	730	1192	860	631	886	1890	987	1939	1018	1067	1462
KAPL	2626	872	885	1099	1790	1393	688	291	416	1827	2076	2959	961	2979	314	2256	2660
LBL	719	2592	2563	2322	1485	2945	2543	3005	2538	1283	1185	45	2791	47	2697	1509	753
LLNL	678	2551	2523	2327	1445	2904	2552	3014	2547	1292	1145	0	2750	64	2706	1468	712
LANL	997	1509	1480	1319	402	2048	1632	2094	1762	452	102	1233	1742	1294	1921	693	1031
Mound	2047	335	348	441	1137	1001	152	614	282	1250	1423	2441	656	2473	440	1561	2081
NRF	712	2077	2048	1766	1468	2617	1986	2448	1982	716	1168	972	2311	1004	2140	1759	746
NTS	0	2180	2151	1864	1209	2720	2158	2620	2214	836	909	678	2414	739	2373	1365	46
ORISE	2180	0	10	333	1125	692	358	702	595	1383	1411	2551	369	2584	753	1410	2214
ORR	2151	10	0	304	1096	685	371	715	608	1354	1382	2523	379	2584	766	1381	2185
PGDP	1864	333	304	0	940	874	0	1009	687	1072	1226	2327	568	2359	845	1258	1903
Pantex	1209	1125	1096	940	0	1664	1248	1710	1378	774	304	1445	1358	1506	1537	308	1243
Pinellas	2720	692	685	874	1664	0	1024	1152	1261	1924	1950	2904	620	2969	1419	1762	2754
PORTS	2158	358	371	0	1248	1024	0	588	276	1361	1534	2552	540	2584	434	1632	2192
PPPL	2620	702	715	1009	1710	1152	588	0	528	1823	1997	3014	767	3046	489	2086	2654
RMI	2214	595	608	687	1378	1261	276	528	0	1415	1664	2547	726	2579	162	1822	2248
RFETS	836	1383	1354	1072	774	1924	1361	1823	1415	0	474	1292	1618	1324	1573	1067	868
SNL-NM	909	1411	1382	1226	304	1950	1534	1997	1664	474	0	1145	1644	1198	1823	605	943
SNL-CA	678	2551	2523	2327	1445	2904	2552	3014	2547	1292	1145	0	2750	64	2706	1468	712
SRS	2414	369	379	568	1358	620	540	767	726	1618	1644	2750	0	2820	1023	1524	2448
SLAC	739	2584	2584	2359	1506	2969	2584	3046	2579	1324	1198	64	2820	0	2738	1529	773
WVDP	2373	753	766	845	1537	1419	434	489	162	1573	1823	2706	1023	2738	0	1980	2407
WIPP	1365	1410	1381	1258	308	1762	1632	2086	1822	1067	605	1468	1524	1529	1980	0	1399
YM	46	2214	2185	1903	1243	2754	2192	2654	2248	868	943	712	2448	773	2407	1399	0

[a]Truck routes generated by using the HIGHWAY 3.1 routing model (Johnson et al., 1993a).

Note: Ames = Ames Laboratory; ANL-E = Argonne National Laboratory-East; ANL-W = Argonne National Laboratory-West; BCL = Battelle Columbus Laboratories; Bettis = Bettis Atomic Power Laboratory; BNL = Brookhaven National Laboratory; Fermi = Fermi National Accelerator Laboratory; FEMP = Fernald Environmental Management Project; HS = Hanford Site; INEL = Idaho National Engineering Laboratory; ITRI = Inhalation Toxicology Research Institute; KCP = Kansas City Plant; KAPL-S = Knolls Atomic Power Laboratory (Schenectady); LBL = Lawrence Berkeley Laboratory; LLNL = Lawrence Livermore National Laboratory; LANL = Los Alamos National Laboratory; Mound = Mound Plant; NRF = Naval Reactor Facility; NTS = Nevada Test Site; ORISE = Oak Ridge Institute for Science and Education; ORR = Oak Ridge Reservation; PGDP = Paducah Gaseous Diffusion Plant; Pantex = Pantex Plant; Pinellas = Pinellas Plant; PORTS = Portsmouth Gaseous Diffusion Plant; PPPL = Princeton Plasma Physics Laboratory; RMI = Reactive Metals, Inc.; RFETS = Rocky Flats Environmental Technology Site; SNL-NM = Sandia National Laboratories (New Mexico); SNL-CA = Sandia National Laboratories (California); SRS = Savannah River Site; SLAC = Stanford Linear Accelerator Center; WVDP = West Valley Demonstration Project; WIPP = Waste Isolation Pilot Plant; and YM = Yucca Mountain.

Table E–3. Rail Route Distances (mi) Between Major DOE Sites[a]

	Ames	ANL-E	ANL-W	BCL	Bettis	BNL	Fermi	FEMP	Hanford	INEL	ITRI	KCP	KAPL-S	LBL	LLNL	LANL	Mound	NRF
Ames	0	329	1242	700	823	1365	291	717	1788	1242	1187	275	1126	1873	2018	1124	715	1242
ANL-E	329	0	1655	401	518	1066	49	412	2201	1655	1351	439	827	2549	2506	1288	416	1655
ANL-W	1242	1655	0	1942	2133	2607	1533	1907	658	0	1247	1238	2468	1102	1100	1179	1926	0
BCL	700	401	1942	0	280	855	427	135	2488	1942	1759	753	615	2573	2718	1696	65	1942
Bettis	823	518	2133	280	0	772	543	475	2611	2133	1857	943	533	2696	2840	1794	345	2133
BNL	1365	1066	2607	855	772	0	1088	984	3153	2607	2414	1518	239	3238	3383	2351	920	2607
Fermi	291	49	1533	427	543	1088	0	441	1971	1533	1356	453	853	2343	2341	1405	443	1533
FEMP	717	412	1907	135	475	984	441	0	2505	1907	1751	717	745	2590	2735	1688	69	1907
Hanford	1788	2201	658	2488	2611	3153	1971	2505	0	658	1793	1784	2914	986	973	1725	2472	658
INEL	1242	1655	0	1942	2133	2607	1533	1907	658	0	1247	1238	2468	1102	1100	1179	1926	0
ITRI	1187	1351	1247	1759	1857	2414	1356	1751	1793	1247	0	932	2177	1266	1222	104	1767	1247
KCP	275	439	1238	753	943	1518	453	717	1784	1238	932	0	1250	2016	2013	869	708	1238
KAPL-S	1126	827	2468	615	533	239	853	745	2914	2468	2177	1250	0	2999	3144	2122	680	2468
LBL	1873	2549	1102	2573	2696	3238	2343	2590	986	1102	1266	2016	2999	0	46	1354	2717	1102
LLNL	2018	2506	1100	2718	2840	3383	2341	2735	973	1100	1222	2013	3144	46	0	1326	2695	1100
LANL	1124	1288	1179	1696	1794	2351	1405	1688	1725	1179	104	869	2122	1354	1326	0	1704	1179
Mound	715	416	1926	65	345	920	443	69	2472	1926	1767	708	680	2717	2695	1704	0	1926
NRF	1242	1655	0	1942	2133	2607	1533	1907	658	0	1247	1238	2468	1102	1100	1179	1926	0
NTS	1674	2348	756	2374	2496	3039	1997	2391	1302	756	1065	1670	2800	860	1370	1169	2386	756
ORISE	956	651	2099	366	714	1221	679	331	2644	2099	1989	881	981	2890	2868	1926	301	2099
ORR	954	649	2055	393	903	1152	682	358	2601	2055	1749	838	957	2686	2831	1686	328	2055
PGDP	646	390	1699	581	816	1346	469	468	2245	1699	1539	482	1106	2490	2469	1476	564	1699
Pantex	809	972	1141	1381	1479	2035	977	1373	1686	1141	379	554	1807	1561	1534	483	1396	1141
Pinellas	1623	1319	2721	1151	1293	1585	1344	1116	3267	2721	2079	1503	1390	3278	3491	2183	1086	2721
PORTS	727	422	1975	91	429	921	451	207	2515	1975	1761	758	681	2767	2745	1698	156	1975
PPPL	1197	898	2507	655	400	410	924	938	2985	2507	2248	1289	214	3298	3276	2186	719	2507
RMI	717	418	2060	207	136	648	445	337	2505	2060	1769	842	408	2851	2829	1706	272	2060
RFETS	782	1194	738	1502	1692	2266	1016	1466	1284	738	572	778	2027	1320	1394	504	1485	738
SNL-NM	1187	1351	1247	1759	1857	2414	1356	1751	1793	1247	0	932	2177	1266	1222	104	1767	1247
SNL-CA	2018	2506	1100	2718	2840	3383	2341	2735	973	1100	1222	2013	3144	46	0	1326	2695	1100
SRS	1281	976	2407	740	947	1239	1001	774	2953	2407	2315	1161	1044	3192	3183	2252	744	2407
SLAC	1924	2536	1160	2947	2746	3289	2393	2641	1036	1160	1253	2073	3050	56	60	1357	2930	1160
WVDP	881	579	2123	370	244	549	603	631	2669	2123	1929	1033	309	2773	2898	1866	562	2123
WIPP	1115	1279	1447	1688	1785	2342	1284	1679	1993	1447	477	861	2114	1660	1633	581	1703	1447
YM	1674	2348	756	2374	2496	3039	1997	2391	1302	756	1065	1670	2800	860	1370	1169	2386	756

Table E-3. Rail Route Distances (mi) Between Major DOE Sites[a]—Continued

	NTS	ORISE	ORR	PGDP	Pantex	Pinellas	PORTS	PPPL	RMI	RFETS	SNL-NM	SNL-CA	SRS	SLAC	WVDP	WIPP	YM
Ames\	1674	956	954	646	809	1623	727	1197	717	782	1187	2018	1281	1924	881	1115	1674
ANL-E	2348	651	649	390	972	1319	422	898	418	1194	1351	2506	976	2536	579	1279	2348
ANL-W	756	2099	2055	1699	1141	2721	1975	2507	2060	738	1247	1100	2407	1160	2123	1447	756
BCL	2374	366	393	581	1381	1151	91	655	207	1502	1759	2718	740	2947	370	1688	2374
Bettis	2496	714	903	816	1479	1293	429	400	136	1692	1857	2840	947	2746	244	1785	2496
BNL	3039	1221	1152	1346	2035	1585	921	410	648	2266	2414	3383	1239	3289	549	2342	3039
Fermi	1997	679	682	469	977	1344	451	924	445	1016	1356	2341	1001	2393	603	1284	1997
FEMP	2391	331	358	468	1373	1116	207	938	337	1466	1751	2735	774	2641	631	1679	2391
Hanford	1302	2644	2601	2245	1686	3267	2515	2985	2505	1284	1793	973	2953	1036	2669	1993	1302
INEL	756	2099	2055	1699	1141	2721	1975	2507	2060	738	1247	1100	2407	1160	2123	1447	756
ITRI	1065	1989	1749	1539	379	2079	1761	2248	1769	572	0	1222	2315	1253	1929	477	1065
KCP	1670	881	838	482	554	1503	758	1289	842	778	932	2013	1161	2073	1033	861	1670
KAPL-S	2800	981	957	1106	1807	1390	681	214	408	2027	2177	3144	1044	3050	309	2114	2800
LBL	860	2890	2686	2490	1561	3278	2767	3298	2851	1320	1266	46	3192	56	2773	1660	860
LLNL	1370	2868	2831	2469	1534	3491	2745	3276	2829	1394	1222	0	3183	60	2898	1633	1370
LANL	1169	1926	1686	1476	483	2183	1698	2186	1706	504	104	1326	2252	1357	1866	581	1169
Mound	2386	301	328	564	1396	1086	156	719	272	1485	1767	2695	744	2930	562	1703	2386
NRF	756	2099	2055	1699	1141	2721	1975	2507	2060	738	1247	1100	2407	1160	2123	1447	756
NTS	0	2530	2487	2131	1376	3153	2401	2871	2391	987	1065	1370	2839	862	2554	1475	0
ORISE	2530	0	40	632	1611	786	392	1176	575	1658	1989	2868	443	3103	889	1918	2530
ORR	2487	40	0	527	1371	797	442	760	600	1586	1749	2831	417	3031	889	1678	2487
PGDP	2131	632	527	0	1103	1056	495	1145	698	1220	1539	2469	714	2597	861	1410	2131
Pantex	1376	1611	1371	1103	0	1825	1382	1867	1387	465	379	1534	1937	1564	1551	307	1376
Pinellas	3153	786	797	1056	1825	0	1106	1207	1361	2280	2079	3491	485	3280	1568	2019	3153
PORTS	2401	392	442	495	1382	1106	0	838	279	1535	1761	2745	655	2651	585	1689	2401
PPPL	2871	1176	760	1145	1867	1207	838	0	511	2066	2248	3276	848	3121	426	2185	2871
RMI	2391	575	600	698	1387	1361	279	511	0	1619	1769	2829	920	2641	163	1705	2391
RFETS	987	1658	1586	1220	465	2280	1535	2066	1619	0	572	1394	1938	1377	1782	769	987
SNL-NM	1065	1989	1749	1539	379	2079	1761	2248	1769	572	0	1222	2315	1253	1929	477	1065
SNL-CA	1370	2868	2831	2469	1534	3491	2745	3276	2829	1394	1222	0	3183	60	2898	1633	1370
SRS	2839	443	417	714	1937	485	655	848	920	1938	2315	3183	0	3194	1223	2243	2839
SLAC	862	3103	3031	2597	1564	3280	2651	3121	2641	1377	1253	60	3194	0	2804	1662	862
WVDP	2554	889	889	861	1551	1568	585	426	163	1782	1929	2898	1223	2804	0	1858	2540
WIPP	1475	1918	1678	1410	307	2019	1689	2185	1705	769	477	1633	2243	1662	1858	0	1475
YM	0	2530	2487	2131	1376	3153	2401	2871	2391	987	1065	1370	2839	862	2540	1475	0

[a]Rail routes generated by using the INTERLINE 5.0 routing model (Johnson et al., 1993b).

Note: Ames = Ames Laboratory; ANL-E = Argonne National Laboratory-East; ANL-W = Argonne National Laboratory-West; BCL = Battelle Columbus Laboratories; Bettis = Bettis Atomic Power Laboratory; BNL = Brookhaven National Laboratory; Fermi = Fermi National Accelerator Laboratory; FEMP = Fernald Environmental Management Project; HS = Hanford Site; INEL = Idaho National Engineering Laboratory; ITRI = Inhalation Toxicology Research Institute; KCP = Kansas City Plant; KAPL-S = Knolls Atomic Power Laboratory (Schenectady); LBL = Lawrence Berkeley Laboratory; LLNL = Lawrence Livermore National Laboratory; LANL = Los Alamos National Laboratory; Mound = Mound Plant; NRF = Naval Reactor Facility; NTS = Nevada Test Site; ORISE = Oak Ridge Institute for Science and Education; ORR = Oak Ridge Reservation; PGDP = Paducah Gaseous Diffusion Plant; Pantex = Pantex Plant; Pinellas = Pinellas Plant; PORTS = Portsmouth Gaseous Diffusion Plant; PPPL = Princeton Plasma Physics Laboratory; RMI = Reactive Metals, Inc.; RFETS = Rocky Flats Environmental Technology Site; SNL-NM = Sandia National Laboratories (New Mexico); SNL-CA = Sandia National Laboratories (California); SRS = Savannah River Site; SLAC = Stanford Linear Accelerator Center; WVDP = West Valley Demonstration Project; WIPP = Waste Isolation Pilot Plant; and YM = Yucca Mountain.

Routes are calculated within the model by minimizing the total impedance between origin and destination. The impedance is basically defined as a function of distance and driving time along a particular segment of highway. A special feature of the HIGHWAY 3.1 model is its ability to calculate routes that maximize the use of interstate highways. This feature allows the user to predict routes for shipping radioactive materials that conform to DOT transportation regulations, specifically HM-164. The population densities along a route are derived from 1990 census data from the U.S. Bureau of the Census. Rural, suburban, and urban areas are characterized according to the following breakdown: rural population densities range from 0 to 54 persons per square kilometer (km^2) (0 to 139 persons per square mile [mi^2]); the suburban range is 55 to 1,284/km^2 (140 to 3,326/mi^2); and urban covers all population densities greater than 1,284/km^2 (3,326/mi^2).

E.4.2.1.2 *INTERLINE 5.0*

The INTERLINE 5.0 computer program is designed to simulate routing of the U.S. rail system. The INTERLINE database consists of 94 separate subnetworks and represents various competing rail companies in the United States. The database used by INTERLINE was originally based on data from the Federal Railroad Administration and reflected the U.S. railroad system in 1974. The database has been expanded and modified over the past two decades. The code is updated periodically to reflect current track conditions and has been compared with reported mileages and observations of commercial rail firms.

The INTERLINE 5.0 model uses a shortest route algorithm that finds the path of minimum impedance within an individual subnetwork. A separate method is used to find paths along the subnetworks. The routes chosen for this study used the standard assumptions in the INTERLINE model that simulate the process of selection that railroads would use to direct shipments of radioactive waste. For Sites that do not have direct rail access, the rail siding nearest the Site was used for routing. The population densities along a route are derived from 1990 census data. Rural, suburban, and urban areas are characterized according to the following breakdown: rural population densities range from 0 to 54 persons per square kilometer (km^2) (0 to 139/mi^2); the suburban range for population density is 55 to 1,284/km^2 (140 to 3,326/mi^2); and urban covers all population densities greater than 1,284/km^2 (3,326/mi^2).

E.4.2.2 Onsite Transportation

Most radioactive waste at the Hanford Site is shipped by truck. The routes for onsite transportation used for this analysis are typical of those used for shipping radioactive waste onsite at the Hanford Site (DOE, 1989). Because the Hanford Site maintains an extensive onsite railroad network, consideration of rail transport was included to maintain consistency with the analyses of offsite transportation. Rail routes were chosen to minimize distance traveled.

E.5 Methods for Calculating Transportation-Related Risks

The technical approach for conducting the transportation risk assessment was developed after a thorough and critical review of the literature and existing documentation in the National Environmental Policy Act for Federal actions involving transportation of radioactive materials. Consideration was also given to recent DOE commitments arising from litigation and public awareness. The approach selected uses several computer models and databases to determine risks for each case. The method for offsite assessment is discussed in Section E.5.1; the method for onsite assessment is discussed in Section E.5.2.

E.5.1 Offsite Transportation

The approach for offsite transportation risk assessment is summarized in Figure E–3 and discussed in detail in this section. For each case, risks are assessed for routine transportation and accidents. For the routine assessment, risks are calculated for the collective populations of potentially exposed individuals, as well as for the MEIs. The accident assessment consists of two components: (1) an accident risk assessment, which considers the probabilities and consequences of a range of possible transportation-related accidents, including low-probability accidents that have high consequences, and high-probability accidents that have low consequences; and (2) an accident consequence assessment, which considers only the radiological consequences of the severe transportation-related accidents that are postulated to result in the largest releases of radioactive material.

The RADTRAN 4 computer code (Neuhauser and Kanipe, 1993) is used for routine and accident risk assessments to estimate the impacts to collective populations. RADTRAN 4 was developed by SNL-NM to calculate population risks associated with transporting radioactive materials by various means,

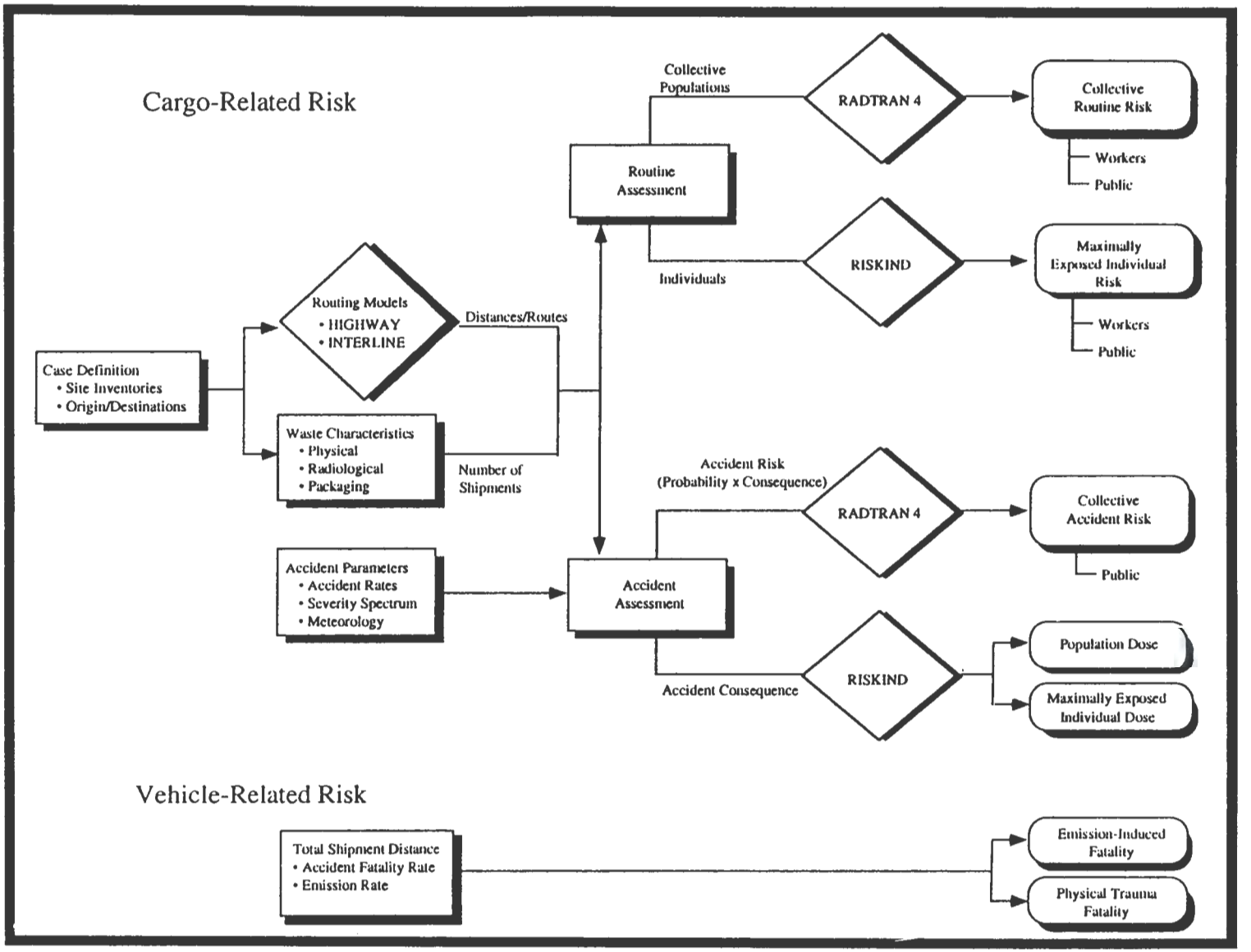

Figure E–3. Approach for the Offsite Transportation Radiological Risk Assessment.

including truck, rail, air, ship, and barge. The code has been extensively reviewed, updated, and used for transportation risk assessments since it was issued in the late 1970s.

The RADTRAN 4 calculations of population risk take into account the consequences and the probabilities of potential exposures. The collective population risk is a measure of the total radiological risk posed to society as a whole by the Alternative being considered. The collective population risks are used as the primary means of comparing the various Alternatives.

As a complement to the RADTRAN calculations, the RISKIND computer code (Yuan et al., 1993) is used to estimate scenario-specific doses to MEIs for routine operations and accidents and to estimate population impacts for the accident consequence assessment. The RISKIND computer code was developed for the DOE Office of Civilian Radioactive Waste Management specifically to analyze radiological consequences to individuals and population subgroups associated with transporting spent nuclear fuel. Minor modifications to the code were made for WM PEIS applications to accommodate shipments of all types of radioactive waste.

The RISKIND calculations are conducted for the WM PEIS to supplement the results for collective risk calculated with RADTRAN 4. Whereas the results for collective risk provide a measure of the overall risks of each case, the RISKIND calculations are meant to address areas of specific concern to individuals and subgroups of population. Essentially, the RISKIND analyses are meant to address hypothetical questions, such as, "What if I live next to a Site access road?" or "What if an accident happens near my town?"

E.5.1.1 Routine (Incident-Free) Risk Assessment Method

E.5.1.1.1 *Collective Population Risk*

The radiological risk associated with routine transportation results from the potential exposure of people to low-level external radiation from loaded shipments. The maximum allowable external dose rates for exclusive-use shipments were presented in Section E.3.1.

For routine transportation, the RADTRAN 4 computer code considers all major groups of potentially exposed persons. The RADTRAN 4 calculations of risk for routine highway and rail transportation include exposures of the following population groups:

1. *Persons Along the Route (Off-Link Population)*. Collective doses are calculated for all persons living or working within 0.8 km (0.5 mi) on each side of a transportation route. The total number of persons within the 1.6-km (1-mi) corridor is calculated separately for each route considered in the assessment.

2. *Persons Sharing the Route (On-Link Population)*. Collective doses are calculated for persons in all vehicles sharing the transportation route. This group includes persons traveling in the same or the opposite direction as the shipment, as well as persons in vehicles passing the shipment.

3. *Persons at Stops*. Collective doses are calculated for people who may be exposed while a shipment is stopped en route. For truck transportation, these include stops for refueling, food, and rest. For rail transportation, stops are assumed to occur for purposes of classification.

4. *Crew Members*. Collective doses are calculated for truck and rail transportation crew members.

The doses calculated for the first three population groups are added generically to yield the collective dose to the public; the dose calculated for the fourth group represents the collective dose to workers. The RADTRAN 4 models for routine dose are not intended to be used for estimating specific risks to individuals.

The RADTRAN 4 calculations for routine dose are based on generically expressing the dose rate as a function of distance from a point source (Neuhauser and Kanipe, 1993). Associated with the calculation of routine doses for each exposed population group are parameters such as the radiation field strength, source-receptor distance, duration of exposure, vehicular speed, stopping time, traffic density, and route characteristics such as population density. The RADTRAN manual contains derivations of the equations and descriptions of these parameters (Neuhauser and Kanipe, 1993). The values for many of the most important parameters are presented in Section E.6.

The collective routine risks are calculated for each specific Alternative as follows. Each Alternative is first defined as a set of origin-and-destination pairs. Representative highway and rail routes are determined for each unique pair, as described in Section E.4. The number of shipments transported across each linkage is then calculated for truck and rail modes by using estimated Site-specific waste inventories and information on shipment capacity, which is in Section E.3. For shipments between each origin-and-destination pair, RADTRAN 4 is used to calculate collective risks to workers and the public on the basis of representative radiological and physical properties of the waste type being considered.

The collective risks are then summed over the set of origin-destination pairs to estimate the collective routine risks associated with that case.

E.5.1.1.2 *Maximally Exposed Individual Risk*

In addition to assessing the routine collective population risk, the RISKIND model has been used to estimate risk to MEIs for a number of hypothetical exposure scenarios. The receptors include transportation crew members, departure inspectors, and members of the public exposed during traffic delays, while working at a service station, or while living near a DOE Site.

The dose to each MEI considered is calculated with RISKIND for an exposure scenario defined by a given distance, duration, and frequency of exposure specific to that receptor. The distances and durations of exposure are similar to those given in previous transportation risk assessments (DOE, 1987b; DOE, 1990a) and are presented in Section E.6. The scenarios are not intended to be exhaustive but were selected to provide a range of potential exposure situations.

The RISKIND external dose model considers direct external exposure and exposure from radiation scattered from the soil and air. The RISKIND model is used to calculate dose as a function of distance (millirems per hour) for stationary exposures and millirems per event (for moving shipments) from a waste shipment on the basis of the shipment dimensions. The code approximates the shipment as a cylindrical volume source; and the calculated dose includes secondary radiation-scattering contributions from buildup (scattering by waste contents), cloudshine (scattering by air), and groundshine (scattering by the ground). The dose rates calculated by using RISKIND have been shown to be comparable with output from existing shielding codes for various waste configurations. The RISKIND model produces realistic but conservative results. As a conservative measure, credit for potential shielding between the cask and the receptor is not considered, although RISKIND allows for shielding provisions.

E.5.1.1.3 *Vehicle-Related (Nonradiological) Routine Risk*

Vehicle-related health risks resulting from routine transportation may be associated with the transporting vehicles that generate air pollutants during waste shipment, independent of the nature of the shipment. The health endpoint assessed under routine transport conditions is the excess (additional)

latent mortality caused by inhalation of vehicular exhaust emissions. A risk factor for latent mortality from pollutant inhalation, generated by Rao et al. (1982), is 1×10^{-7}/km (1.6×10^{-7}/mi) of truck travel in an urban area. This risk factor is based on regression analyses of the effect of sulfur dioxide and particulate releases from diesel exhaust on mortality. Excess latent mortality is assumed to be equivalent to cancer fatalities. Vehicle-related risks from routine transportation are calculated for each case by multiplying the total distance traveled in urban areas by the appropriate risk factor. Similar risk factors are not available for rural and suburban areas.

Risks are summed over the entire route and over all shipments for each Alternative. This method has been used in several reports to calculate risks from routine transport of radioactive wastes (DOE, 1986b; DOE, 1987a; DOE, 1990a) and provides a convenient method of comparing the risks of routine transport for HW shipment alternatives and the risks of HW versus radioactive waste shipments under routine conditions. Lack of information for rural and suburban areas is an obvious gap in the data, although the risk factor would presumably be lower because total emissions from all sources in rural and suburban areas are lower.

E.5.1.2 Accident Assessment Method

E.5.1.2.1 *Radiological Accident Risk Assessment*

The risk analysis for potential accidents differs fundamentally from the risk analysis for routine transportation because occurrences of accidents are statistical. The accident risk assessment is treated probabilistically in RADTRAN 4. Accident risk is defined as the product of the accident consequence (dose) and the probability of the accident occurring. In this respect, the RADTRAN 4 code estimates the collective accident risk to populations by considering a spectrum of transportation-related accidents. The spectrum of accidents is designed to encompass a range of possible accidents, including low-probability accidents with high consequences and high-probability accidents with low consequences ("fender benders"). The results for collective accident risk can be directly compared with the results for routine collective risk because the former results incorporate the probabilities of accident occurrences.

The RADTRAN 4 calculation of collective accident risk employs models that quantify the range of potential accident severities and the responses of transported packages to accidents. The spectrum of

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accident severity is divided into a number of categories. Each category of severity is assigned a conditional probability of occurrence—that is, the probability that an accident will be of a particular severity if an accident occurs. The more severe the accident, the more remote the chance of such an accident. Release fractions, defined as the fraction of the material in a package that could be released in an accident, are assigned to each accident severity category on the basis of the physical and chemical form of the waste material. The models take into account the transportation mode and the packaging type being considered. The accident rates, the definition of accident severity categories, and the release fractions used in this analysis are discussed further in Section E.6.

For accidents involving the release of radioactive material, RADTRAN 4 assumes that the material is dispersed into the environment according to standard Gaussian diffusion models. For the risk assessment, default data for atmospheric dispersion were used, representing an instantaneous ground-level release and a small-diameter source cloud (Neuhauser and Kanipe, 1993). The calculation of the collective population dose after the release and dispersal of radioactive material includes the following exposure pathways:

- External exposure to the passing radioactive cloud
- External exposure to contaminated soil
- Internal exposure from inhaling airborne contaminants
- Internal exposure from ingesting contaminated food

For the pathway of ingestion, State-specific food transfer factors, which relate the amount of radioactive material ingested to the amount deposited on the ground, were calculated in accordance with the methods described by NRC Regulatory Guide 1.109 (NRC, 1977b) and were used as input to the RADTRAN code. Doses of radiation from ingesting or inhaling radionuclides are calculated with standard dose conversion factors (DOE, 1988a; DOE, 1988b).

The collective accident risk for each case is determined in a manner similar to that described for routine collective risks. Accident risks are first calculated for each unique origin-and-destination pair and then are summed over all pairs to estimate the total risk for the case. The accident risk assessment uses site-specific and waste type-specific radiological and physical waste characteristics, which are described further in Section E.6. In addition, the assessment uses route-specific information on population density and accident rates derived for individual States.

E.5.1.2.2 *Radiological Accident Consequence Assessment*

The RISKIND code is used to provide a scenario-specific assessment of radiological consequences of severe transportation-related accidents for each waste type. The RADTRAN 4 accident risk assessment considers the entire range of accident severities and their related probabilities, whereas the RISKIND accident consequence assessment focuses on accidents that result in the largest releases of radioactive material to the environment.

For each waste type, accident consequences are presented for a shipment of waste that represents the highest potential radiological risk if an accident occurs. This "worst case" is identified for each waste type by screening the site-specific radiological waste characteristics (that is, activity concentrations) developed for this PEIS, taking into account the physical forms of waste and the relative hazards of individual radionuclides. For most waste shipments, the consequences of severe accidents would be less than those presented for the worst case. The accident consequence assessment is intended to provide an estimate of the maximum potential impacts posed by a severe transportation-related accident involving a particular waste type.

The severe accidents considered in the consequence assessment are characterized by extreme mechanical and thermal forces. In all cases, these accidents result in a release of radioactive material to the environment. The accidents correspond to those within the highest accident severity category, as described previously. These accidents represent low-probability high-consequence events. Therefore, accidents of this severity are expected to be extremely rare. However, the overall probability that such an accident could occur is dependent upon the potential accident rates for this severity category and the shipping distance for each case.

The RISKIND model was used to assess accident consequences for two reasons. First, its code can model the complex atmospheric (or site-specific) dispersion from severe accidents. The atmospheric dispersion is modeled as an instantaneous release by using standard Gaussian puff methods. In addition, because severe accidents routinely involve fires, modeling the potential radiological consequences takes into account physical phenomena resulting from the fire, such as buoyant plume rise. Second, RISKIND can estimate the dose to MEIs near an accident. RISKIND is used to determine the MEI's location on the basis of the atmospheric conditions assumed at the time of the accident and the thermal characteristics of the release.

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For each waste type, the accident consequences are calculated for local populations and for MEIs. The population dose includes the population within 80 km (50 mi) of the accident site. The exposure pathways considered are similar to those discussed previously for the accident risk assessment. Although remedial activities after the accident (for example, evacuation or ground cleanup) would reduce the consequences, these activities were not considered in the consequence assessment.

Because predicting the exact location of a severe transportation-related accident is impossible, separate consequences are calculated for accidents occurring in rural, suburban, and urban zones of population density. Moreover, to address the effects of the atmospheric conditions existing at the time of an accident, two different atmospheric conditions are considered. The first case assumes neutral atmospheric conditions, and the second assumes stable conditions. Atmospheric conditions are discussed further in Section E.6.

E.5.1.2.3 *Vehicle-Related (Nonradiological) Accident Risk Assessment*

The vehicle-related accident risk refers to the potential for transportation-related accidents that directly result in fatalities that are not related to the shipment's cargo. This risk represents fatalities from mechanical causes. State-specific transportation fatality rates are used in the assessment and are discussed in Section E.6. Vehicle-related accident risks are calculated for each case by multiplying the total distance traveled in each State by the appropriate State rate for transportation-related fatalities. In all cases, the vehicle-related accident risks are calculated by using distances for round-trip shipment.

E.5.2 ONSITE TRANSPORTATION

The RISKIND computer code was used to calculate the routine and accident doses to MEIs and to collective onsite populations from onsite transportation at the Hanford Site. The RISKIND code allows for extensive use of site-specific data. Sitewide characteristics, such as weather data, nonuniform population densities, and surrounding agricultural productivity, are variable input parameters. In addition, the characteristics of receptors, such as shielding, intake rates, and location relative to the shipping route, can be specified.

E.5.2.1 Routine (Incident-Free) Risk Assessment Method

For routine conditions, RISKIND is used to calculate the dose and risk to specific individuals distinguished by their location relative to a shipment when it is stationary or moving. As a conservative assumption, potential shielding between the waste shipments and the receptor is not considered.

The following four groups of receptors are considered for the onsite routine risk assessment:

- Truck and rail crew members (crew dose)
- Workers near the transportation route (off-link worker population dose)
- Persons sharing the transportation route (on-link dose)
- Guards at the gates of individual facilities or at checkpoints along the route

The dose to the crew members is calculated by multiplying the distance traveled times the dose per kilometer calculated by RADTRAN 4 at the crew compartment. The dose rate in the crew compartment is limited to a value of 2 mrem/h by Federal regulations. RADTRAN 4 was used for estimating the dose to the crew to retain consistency with the offsite transportation assessment.

Onsite workers at the Hanford Site are located within well-defined facilities or work areas. All areas within 0.8 km (0.5 mi) on each side of the route were considered. RISKIND was used to calculate the population dose to each affected area by specifying the minimum distance from the route, the maximum distance from the route, and the average population density of that specific work area. The dose for each area was calculated while the shipment was immediately next to the area.

RISKIND was used to calculate the dose to individuals sharing the truck transportation route with waste shipments on the basis of the average vehicular occupancy and speed, road type, and one-way traffic densities. Members of the public, as well as workers, receive this dose because a section of a principal onsite route is over public-access roadways. No on-link dose was calculated for rail transportation because the tracks at the Hanford Site are used exclusively by Hanford; no parallel sets of tracks exist over the route.

For truck routes, the guard at the boundary of the shipping facility or the one at the checkpoint along the route is potentially the closest individual to the shipment outside of the loading facilities. This dose was calculated directly by using RISKIND.

E.5.2.2 Accident Consequence Assessment Method

For each waste type, the radiological accident consequences of the onsite transportation and its attendant health risks were calculated. The probabilities for onsite transportation accidents at Hanford Site (Wang et al., 1991) were used to estimate the likelihood of potential accidents and the associated maximum credible radioactive release for each waste type.

Doses to an MEI and to onsite and offsite populations are calculated by using RISKIND and parameters specific to Hanford. Doses include contributions from inhalation, cloudshine, and groundshine; no pathway for food ingestion has been considered for MEIs or for onsite worker populations. The food-ingestion pathway was considered only for offsite rural populations.

E.6 Input Parameters and Assumptions

The transportation risk assessment is designed to ensure—through uniform and judicious selection of models, data, and assumptions—that relative comparisons of risk among the various Alternatives are meaningful. This goal is accomplished by uniformly applying to all Alternatives the input parameters and assumptions common to each waste type. The principal input parameters and assumptions used in the transportation risk assessment are discussed in this section.

E.6.1 Waste Inventory and Characterization Data

The computational model WASTE_MGMT was developed at ANL-E to support the PEIS analyses of risks and costs (Kotek et al., 1995). Input to the model includes data on the waste inventory and on waste characterization at each DOE Site, data on operations for the TSD facilities used for the wastes, and definitions of various Alternatives. The sources and development of the model input data are described in the supporting technical reports specific to each waste type (Folga et al., 1995; Goyette, 1995; Hong et al., 1995; Lazaro et al., 1995; Wilkins et al., 1995).

One output of the model consists of the quantity, physical form, and radiological characteristics of the waste shipped between Sites for each case. Table E-4 shows an example of output for an LLW case. The output presents part of a waste transportation data file that includes, for each origin-and-destination pair, the total quantity of waste shipped (both volume and mass), as well as the total

Table E-4. Example of a Partial Argonne National Laboratory WASTE_MGMT Computational Model Output File Used as Input for the Transportation Radiological Risk Assessment[a]

Waste Stream LLW		
Origin Site AMES		
Destination	Volume	Mass
Site NTS	m^3/yr 1.16E+01	kg/yr 2.99E+04
	Radionuclide	Activity Ci/yr
	T1-208	4.50E-07
	Pb-212	1.19E-06
	Bi-212	1.19E-06
	Po-212	7.68E-07
	Po-216	1.19E-06
	Ra-224	1.19E-06
	Ra-228	7.12E-06
	Ac-228	7.12E-06
	Th-228	1.19E-06
	Th-231	6.86E-06
	Th-232	7.23E-05
	Th-234	8.79E-03
	Pa-234	9.01E-07
	Pa-234m	8.79E-03
	U-235	6.83E-06
	U-238	8.79E-03
	Pu-238	6.94E-04
	Pu-239	5.30E-05
	Pu-240	1.85E-04
	Pu-241	2.55E-02
	Am-241	1.06E-06
	Cm-242	1.48E-05
	Cm-244	5.30E-06

[a] A complete WASTE_MGMT output file contains the above shipment information for all origin-and-destination pairs for a given case. For illustrative purposes, only shipments between one origin and one destination are shown.

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activity (curies) of radionuclides in the waste being shipped. The effects of potential waste treatment, such as volume reduction or incineration, are considered in the model and are reflected in changes in waste density and activity concentrations. The WASTE_MGMT output files are used directly as input to the transportation risk assessment.

For each waste type, the physical forms of the waste are generally classified into a small number of categories, such as vitrified waste, liquid waste, metal waste, and heterogeneous solid waste. The package release fractions are developed according to the physical characteristics of the waste in each category.

E.6.2 Shipment External Dose Rates

The dose (and, correspondingly, the risk) to populations and MEIs during routine transportation is directly proportional to the assumed external dose rate from the shipment. The Federal regulations for maximum allowable external dose rates for exclusive-use shipments are presented in Section E.3.1. The actual shipment dose rate is a complex function of the composition and configuration of shielding and containment materials used in the waste packaging, the geometry of the loaded shipments, and the characteristics of the waste material itself. The external dose rates assumed for each waste type are summarized in Table E-5 and are discussed in detail in the text. In practice, external dose rates vary not only from Site to Site and from waste type to waste type but also from shipment to shipment at a given Site.

E.6.2.1 HLW Shipments

For HLW shipments, the external dose rate has been assumed to be equal to the regulatory limit of 10 mrem/h at 2 m (6.6 ft) for all shipments. The regulatory limit was assumed because extensive historical data for HLW shipments do not exist. In practice, the dose rates may range well below the regulatory limit assumed for this assessment. Therefore, assuming that the dose rates are equal to the regulatory limit provides a conservative estimate.

Table E-5. Shipment External Dose Rates for Each Waste Type

Waste Type	External Dose Rate
HLW[a]	10 mrem/h at 2 m (6.6 ft)
LLW[b]	1 mrem/h at 1 m (3.3 ft)
TRUW[c]	CH = 3 mrem/h at 1 m RH = 7 mrem/h at 1 m
LLMW	1 mrem/h at 1 m (3.3 ft)[d]

Notes: CH = contact handled waste; RH = remote-handled waste.
[a] Regulatory limit (10 CFR 71).
[b] Based on historical DOE LLW shipments as reported to the Shipment Mobility/Accountability Collection (R. Morris, Science Applications International Corp., personal communication to F.A. Monette, ANL, Argonne, IL, Dec. 9, 1993).
[c] Derived from DOE (1990a).
[d] Based on comparison of LLMW and LLW radiological characteristics.

E.6.2.2 LLW Shipments

For LLW shipments, the external dose rates from historical waste shipments were investigated by using the Shipment Mobility/Accountability Collection (SMAC) system (personal communication from R. Morris, Science Applications International Corp., to F.A. Monette, ANL, Argonne, IL, Dec. 9, 1993). The SMAC database contains information about unclassified commercial freight shipments made by DOE and its contractors. The information available in the SMAC database is collected from Site shipping and receiving documents. Available information for shipments of radioactive materials includes the types of material shipped, the number of packages in each shipment, shipment weights, external dose rates, and package isotopic inventories. Approximately two-thirds of all DOE unclassified shipments are estimated to be reported to the SMAC database.

Shipment information from the SMAC database was examined for fiscal years 1983 to the present (personal communication from R. Morris, Science Applications International Corp., to F.A. Monette, ANL, Argonne, IL, Dec. 9, 1993). Information was provided for three general categories of radioactive material: irradiated fuel, "other" highway route controlled quantities, and LLW. (The material categories chosen were dictated by the format in which data are submitted and entered into the SMAC database and are not consistent with the definitions of waste types used in this PEIS.) Of the 15,000 LLW shipments recorded in the SMAC database, approximately 2,500 reported external dose

rates. The average dose rate reported was approximately 1 mrem/h, measured at 1 m (3.3 ft) from the surface of a shipment. This value was used for future LLW shipments for the PEIS analysis.

E.6.2.3 TRUW Shipments

For TRUW shipments, external package dose rates have been derived from information in the Supplemental Final Environmental Impact Statement (SFEIS) for WIPP (DOE, 1990a). In the WIPP SFEIS, Site-specific external package dose rates were presented for CH-TRUW and for RH-TRUW packages. For this PEIS, the average external dose rates were calculated by using the SFEIS values and were used for purposes of assessment. The average external package dose rates were calculated to be 3 mrem/h for CH-TRUW and 7 mrem/h for RH-TRUW at 1 m (3.3 ft).

E.6.2.4 LLMW Shipments

Because very limited data exists for historical LLMW shipments, and the fact that the radiological characteristics of LLMW were assumed to be similar to LLW for the PEIS, the external dose rate for shipments of LLMW was assumed to be the same as for the LLW shipments. As with LLW shipments, an average dose rate of 1 mrem/h measured at 1 m (3.3 ft) from the surface of a shipment was assumed for analysis purposes.

E.6.3 Population Density Zones

Three population density zones—rural, suburban, and urban—were used for the offsite population risk assessment. The fractions of travel in each zone were determined by using the HIGHWAY and INTERLINE routing models. The rural, suburban, and urban zones are assigned average population densities of 6/km^2 (15.5/mi^2), 719/km^2 (1,862/mi^2), and 3,861/km^2 (10,000/mi^2), respectively. These population densities are typical of rural, suburban, and urban environments (NRC 1977a). Occurrence of the three population density zones is based on an aggregation of the 12 population density zones provided in the HIGHWAY and INTERLINE model outputs. For calculation purposes, information about population density was generated at the State level and used as RADTRAN input for all origin-and-destination pairs. For the onsite analysis, the population density of the Hanford Site was used.

E.6.4 ACCIDENT RATES

For calculating accident risks, vehicle accident involvement and fatality rates are taken from data provided in Saricks and Kvitek (1994). For each transport mode, accident rates are generically defined as the number of accident involvements (fatalities) in a given year per unit of travel of that mode in the same year. Therefore, the rate is a fractional value—the accident-involvement count is the numerator, and vehicular activity (total traveled distance) is the denominator. Accident rates are generally determined for a multiyear period. For assessment purposes, the total number of expected accidents or fatalities is calculated by multiplying the total shipping distance for a specific case by the appropriate accident or fatality rate.

For truck transportation, the rates presented in Saricks and Kvitek (1994) are specifically for heavy combination trucks involved in interstate commerce. Heavy combination trucks are rigs composed of a separable tractor unit containing the engine and one to three freight trailers connected to each other and the tractor. Heavy combination trucks are typically used for shipping radioactive wastes. Truck accident rates are computed for each State on the basis of statistics compiled by the DOT Office of Motor Carriers for 1986 to 1988. Saricks and Kvitek (1994) present accident involvement and fatality counts, estimated kilometers of travel by State, and the corresponding average accident involvement, fatality, and injury rates for the 3 years investigated. Fatalities (including crew members) are deaths attributable to the accident that occurred any time within 30 days of the accident.

Rail accident rates are computed and presented similarly to truck accident rates in Saricks and Kvitek (1994); however, for rail transport, the unit of haulage is the railcar. State-specific rail accident involvement and fatality rates are based on statistics compiled by the Federal Railroad Administration for 1985 to 1988. Rail accident rates include both mainline accidents and those occurring in rail yards.

The accident assessment presented in this appendix uses separate accident rates for travel in rural, suburban, and urban population density zones in each State. Therefore, total accident risk for a case depends on the total distance traveled in various population zones in each State and does not rely on national average accident statistics. However, for comparative purposes, the national average truck accident rate presented in Saricks and Kvitek (1994) is 2.4×10^{-7} accidents/km (3.9×10^{-7} accidents/mi). The national average railcar accident rate is 5.6×10^{-8} accidents/km (9.0×10^{-8} accidents/mi). For the onsite accident assessment, accident probabilities at the Hanford Site were taken from Wang et al. (1991).

Note that the accident rates used in this assessment were computed using all interstate shipments, regardless of the cargo. Saricks and Kvitek (1994) point out that shippers and carriers of radioactive material generally have a higher-than-average awareness of transportation risk and prepare cargos and drivers for such shipments accordingly. This preparation should have the twofold effect of reducing component and equipment failure and mitigating the contribution of human error to accident causation. These effects were not considered in the accident assessment.

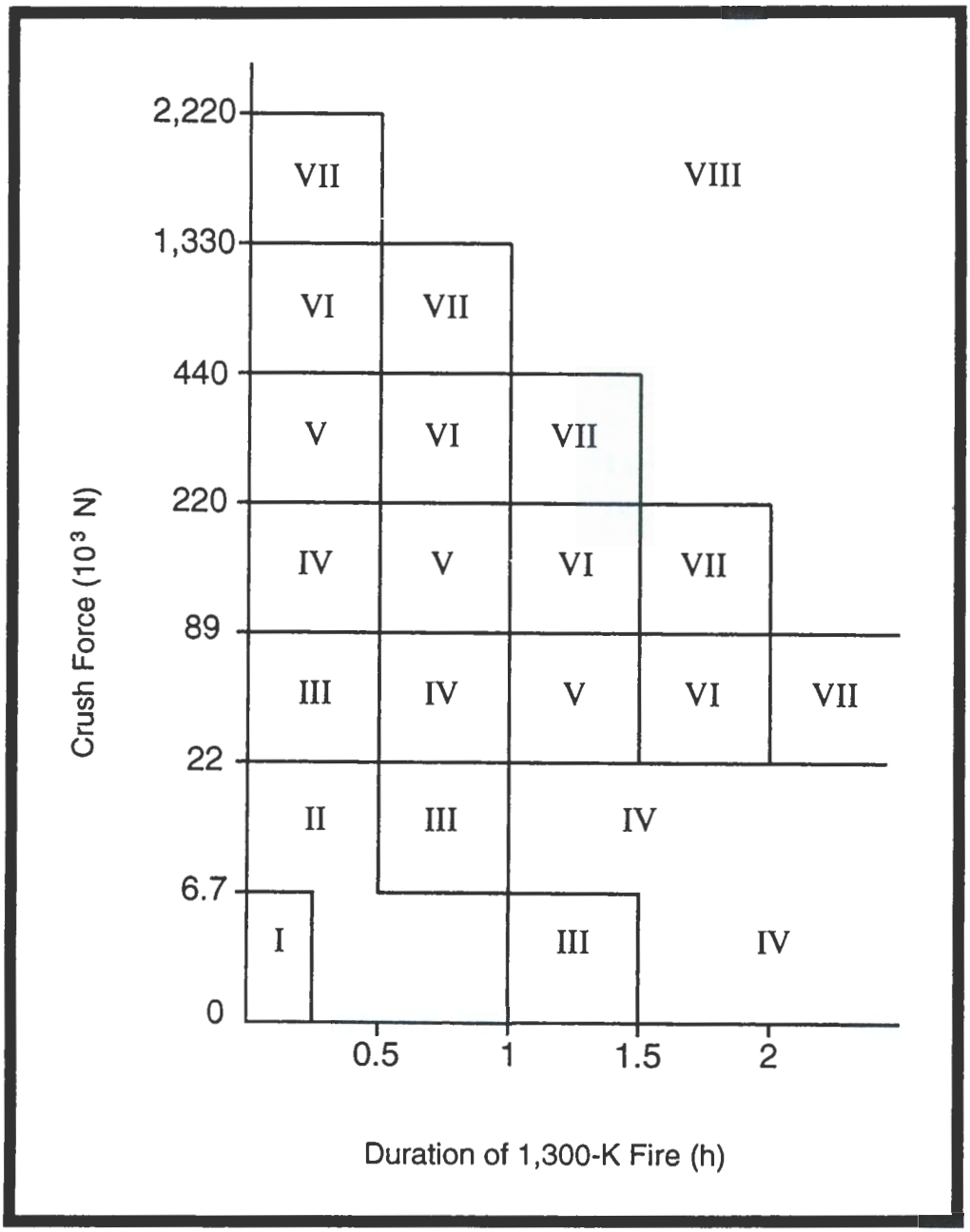
E.6.5 ACCIDENT SEVERITY CATEGORIES

A method to characterize the potential severity of transportation-related accidents is described in a NRC report commonly referred to as NUREG-0170 (NRC, 1977a). The NRC method divides the spectrum of transportation accident severities into eight categories. Other studies have divided the same accident spectrum into 6 categories (Wilmot, 1981) and into 20 categories (Fischer et al., 1987); however, these studies focused primarily on accidents involving spent nuclear fuel shipments.

The NUREG-0170 scheme for accident classification is shown in Figure E–4 for truck transportation, and Figure E–5 for rail transportation. Severity is described as a function of the magnitudes of the mechanical forces (impact) and thermal forces (fire) to which a package may be subjected during an accident. Because all accidents can be described in these terms, severity is independent of the specific accident sequence. In other words, any sequence of events that results in an accident in which a package is subjected to forces within a certain range of values is assigned to the accident severity category associated with that range. The scheme for accident severity is designed to take into account all credible transportation-related accidents, including accidents with low probability but high consequences and those with high probability but low consequences.

Each severity category represents a set of accident scenarios defined by a combination of mechanical and thermal forces. A conditional probability of occurrence (that is, the probability that if an accident occurs, it is of a particular severity) is assigned to each category. The fractional occurrences for accidents by the accident severity category and the population density zone are shown in Table E–6.

Category I accidents are the least severe but the most frequent, whereas Category VIII accidents are very severe but very infrequent. To determine the expected frequency of an accident of a given severity, the conditional probability in the category is multiplied by the baseline accident rate. Each



Source: NRC, 1977a.

Figure E-4. Scheme for NUREG-0170 Classification by Accident Severity Category for Truck Accidents.

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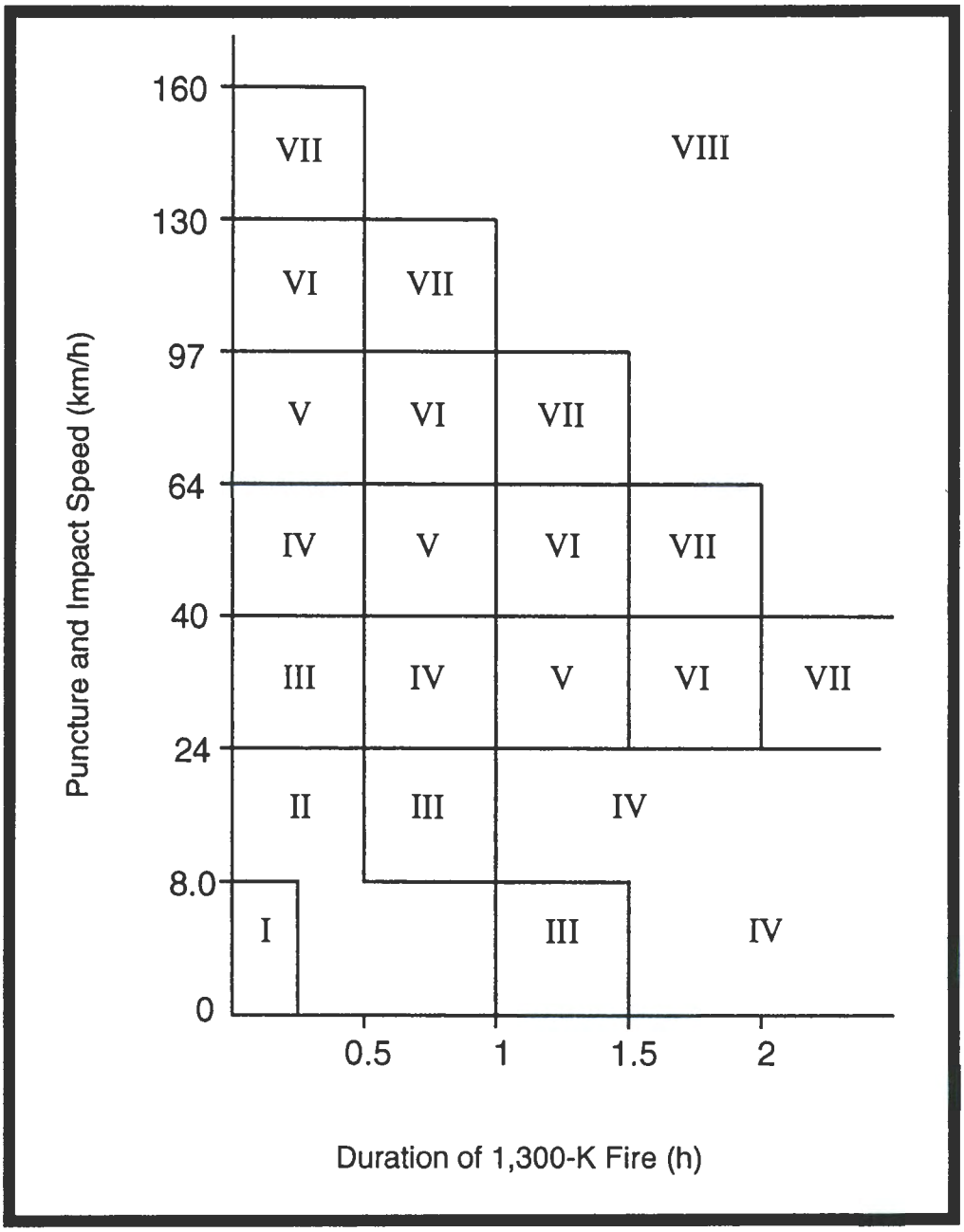

Source: NRC, 1977a

Figure E–5. Scheme for NUREG-0170 Classification by Accident Severity Category for Rail Accidents.

Table E-6. Fractional Occurrences for Accidents by Severity Category and Population Density Zone

Severity Category	Fractional Occurrence	Fractional Occurrence by Population Density Zone		
		Rural	Suburban	Urban
Truck				
I	0.55	0.1	0.1	0.8
II	0.36	0.1	0.1	0.8
III	0.07	0.3	0.4	0.3
IV	0.016	0.3	0.4	0.3
V	0.0028	0.5	0.3	0.2
VI	0.0011	0.7	0.2	0.1
VII	8.5×10^{-5}	0.8	0.1	0.1
VIII	1.5×10^{-5}	0.9	0.05	0.05
Rail				
I	0.50	0.1	0.1	0.8
II	0.30	0.1	0.1	0.8
III	0.18	0.3	0.4	0.3
IV	0.018	0.3	0.4	0.3
V	0.0018	0.5	0.3	0.2
VI	1.3×10^{-4}	0.7	0.2	0.1
VII	6.0×10^{-5}	0.8	0.1	0.1
VIII	1.0×10^{-5}	0.9	0.05	0.05

Source: NRC, 1977a.

population density zone has a distinct baseline accident rate and distribution of accident severities related to differences in average vehicular velocity, traffic density, and other factors, including location—rural, suburban, or urban.

For the accident consequence assessment, the doses were assessed for populations and individuals by assuming an accident of severity Category VIII. This accident severity category represents the most severe accident scenarios, which would result in the largest releases of radioactive material. Accidents of this severity are extremely rare, occurring approximately once in every 70,000 truck or 100,000 rail accidents involving a radioactive waste shipment. On the basis of national accident statistics (Saricks and Kvitek, 1994), for every 1.6 km (1 mi) of shipment (loaded), the probability of an accident of this severity is 6×10^{-12} for shipment by truck and 1×10^{-12} for shipment by rail. For the PEIS waste Alternatives (the largest estimated shipment mileage is 560 million mi for LLW), no accident of such severity is expected to occur.

E.6.6 PACKAGE RELEASE FRACTIONS

Radiological consequences are calculated by assigning package release fractions to each accident severity category. The release fraction is defined as the fraction of the radioactive material in a package that could be released from that package during an accident of a certain severity. Release fractions take into account all mechanisms necessary to create release of radioactive material from a damaged package to the environment. Release fractions vary according to the package type and the physical form of the waste. Type B packagings are designed to withstand the forces of severe accidents and, therefore, have smaller release fractions than Type A packagings.

Package release fractions for accidents of each severity category are given in Table E–7 for the package types considered in this assessment. The values for release fractions were obtained from various

Table E–7. Estimated Release Fractions for Shipping Packagings Under Various Accident Severity Categories

	Estimated Release Fraction			
		Type B		
Severity Category	Type A[a]	HLW Cask[a]	TRUPACT-II[b]	NuPac 72B[b]
Truck				
I	0	0	0	0
II	0.01	0	0	0
III	0.1	0.01	8×10^{-9}	6×10^{-9}
IV	1.0	0.1	2×10^{-7}	2×10^{-7}
V	1.0	1.0	8×10^{-5}	1×10^{-4}
VI	1.0	1.0	2×10^{-4}	1×10^{-4}
VII	1.0	1.0	2×10^{-4}	2×10^{-4}
VIII	1.0	1.0	2×10^{-4}	2×10^{-4}
Rail				
I	0	0	0	0
II	0.01	0	0	0
III	0.1	0.01	2×10^{-8}	2×10^{-8}
IV	1.0	0.1	7×10^{-7}	7×10^{-7}
V	1.0	1.0	8×10^{-5}	1×10^{-4}
VI	1.0	1.0	2×10^{-4}	1×10^{-4}
VII	1.0	1.0	2×10^{-4}	2×10^{-4}
VIII	1.0	1.0	2×10^{-4}	2×10^{-4}

[a] Values are for total material release fraction.
[b] Values are for respirable release fraction.

Sources: NRC, 1977a; DOE, 1990a.

sources, but all were derived on the basis of the methods described in NUREG-0170 (NRC, 1977a). Also important for the purposes of risk assessment are the fraction of the released material that can be entrained in an aerosol (that is, part of an airborne radioactive plume) and the fraction of the aerosolized material that is also respirable (of a size that can be inhaled into the lungs). These fractions depend on the physical form of the waste material. Most solid materials are difficult to release in particulate form and are, therefore, relatively nondispersible. Conversely, liquid or gaseous materials are relatively easy to release if the container is compromised in an accident. The aerosolized and respirable fractions for various physical forms of waste have been compiled in RADTRAN (Neuhauser and Kanipe, 1993) and are given in Table E-8. (Note that the release fractions for TRUW packages incorporate the aerosolized and respirable fractions on the basis of the characteristics of TRUW.)

E.6.7 ATMOSPHERIC CONDITIONS

Radioactive material released to the atmosphere is transported by the wind. The amount of dispersion, or dilution, of the radioactive material in the air depends on the meteorologic conditions at the time of the accident. Because predicting the specific location of an offsite transportation-related accident is impossible, generic atmospheric conditions were selected for the accident risk and consequence assessments.

For the accident risk assessment, neutral weather conditions were assumed; these conditions were represented by Pasquill stability Class D with a windspeed of 4 m/second (s) (9 mi/h). Because neutral meteorologic conditions constitute the most frequently occurring atmospheric stability condition in the

Table E-8. Aerosolized and Respirable Material Release Fractions for Various Physical Waste Forms

Physical Waste Form	Aerosolized Fraction	Respirable Fraction
Vitrified waste[a]	1×10^{-6}	0.05
Activated metals[a]	1×10^{-6}	0.05
Heterogeneous solids[b]	0.1	0.05
Nonvolatile liquids	0.1	0.05
Volatile liquids	1	1

[a] Considered to behave as immobile material.
[b] Considered to behave as a loose powder.

Source: Neuhauser and Kanipe, 1993.

United States, these conditions are most likely to be present if an accident occurs involving a waste shipment. Observations at National Weather Service surface meteorologic stations from more than 300 U.S. locations indicate that on a yearly average, neutral conditions (represented by Pasquill Classes C and D) occur about half (50 percent) the time, while stable conditions occur about one-third (33 percent) of the time (Pasquill Classes E and F), and unstable conditions (Pasquill Classes A and B) occur about one-sixth (17 percent) of the time (Doty et al., 1976). The neutral category predominates in all seasons but is most prevalent (nearly 60 percent of the observations) during winter.

For the accident consequence assessment, doses were assessed under neutral atmospheric conditions (Pasquill Stability Class D with a windspeed of 4 m/s [9 mi/h]) and stable conditions (Pasquill Stability Class F with a windspeed of 1 m/s [2.2 mi/h]). The results calculated for neutral conditions represent the most likely consequences, and the results for stable conditions represent a "worst case" weather situation in which the least amount of dilution is evident with the highest air concentrations of radioactive material.

E.6.8 Health Risk Conversion Factors

The health risk conversion factors used throughout this PEIS to estimate the number of expected cancer-caused fatalities, the incidence of cancer, and the serious genetic effects from radiological exposures were derived from ICRP (1991): 5.0×10^{-4} cases of fatal cancer per person-rem for members of the public, and 4.0×10^{-4} cases for workers; 1.7×10^{-3} cases of induced cancer per person-rem for members of the public, and 1.4×10^{-3} cases for workers; and 1.0×10^{-4} adverse genetic effects per person-rem for members of the public, and 6.0×10^{-5} adverse genetic effects for workers. Cancer-caused fatalities and cancer incidence are determined over the lifetimes of exposed populations. Genetic effects occur in descendants of the exposed population, and the estimates for these effects are based on the total dose to the reproductive organs. The genetic health risk conversion factors used in this analysis include all generations.

E.6.9 Maximally Exposed Individual Exposure Scenarios

The risk to MEIs has been estimated for a number of hypothetical exposure scenarios for offsite transportation. The receptors include crew members, departure inspectors, and members of the public exposed during traffic obstructions (traffic jams), while working at a service station, or by living near

a treatment, storage, or disposal site. The dose and risk to MEIs were calculated for particular distances and durations of exposure. The distances and durations of exposure for each receptor are similar to those used in previous transportation assessments (DOE, 1987b; DOE, 1990a). The scenarios for exposure are not intended to be exhaustive but were selected to provide a range of potential exposure situations. The assumptions for exposure scenarios are as follows:

- *Crew Members*. Truck and rail crew members are assumed to be occupational radiation workers and would be monitored by a dosimetry program. Therefore, the maximum allowable dose would be 5 rem/yr. As an administrative procedure, DOE limits doses to its workers to 2 rem/yr (DOE, 1992b).
- *Inspectors (Truck and Rail)*. Inspectors are assumed to be either Federal or State vehicle inspectors. Inspectors are not assumed to be monitored by a dosimetry program. An average exposure distance of 3 m (9.8 ft) and an exposure duration of 30 minutes are assumed.
- *Rail-Yard Crew Member*. A rail-yard crew member is not assumed to be monitored by a dosimetry program. An average exposure distance of 10 m (32.8 ft) and an exposure duration of 2 hours are assumed.
- *Resident (Truck and Rail)*. A resident is assumed to live 30 m (98 ft) from a Site entrance route (truck or rail). Shipments pass at an average speed of 24 km/h (15 mi/h), and the resident is exposed unshielded. Cumulative doses are assessed for each Site on the basis of the number of shipments entering or exiting the Site, with the assumption that the resident is present for 100 percent of the shipments.
- *Person in Traffic Obstruction (Truck and Rail)*. A person is assumed to be stopped next to a waste shipment (because of traffic or other obstructions). The person is assumed to be exposed unshielded at a distance of 1 m (3.3 ft) for 30 minutes.
- *Person at Truck Service Station*. A person is assumed to be exposed at an average distance of 20 m (65.6 ft) for 2 hours. This receptor could be a worker at a truck stop.
- *Resident Near a Rail Stop*. A resident is assumed to live near a rail classification yard. The resident is assumed to be exposed unshielded at a distance of 200 m (656 ft) for 20 hours.

The largest uncertainty in predicting the dose to MEIs during transportation involves determining the frequency of exposure occurrence. This difficulty arises from uncertainties in future shipment schedules and route selection and from the inherent uncertainty in predicting the frequency of random or chance events; for example, it is conceivable that an individual may be stopped in traffic next to a shipment of radioactive waste, but it is difficult to predict how often the same individual would experience this event. Therefore, doses are assessed on a per-event basis for most receptors considered. To account for possible multiple exposures, ranges of realistic total doses are discussed qualitatively. One exception is the dose calculation for hypothetical residents living near an entrance route to a treatment, storage, or disposal site. For these residents, total doses are calculated on the basis of the number of shipments entering or exiting each Site for each PEIS Alternative.

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E.6.10 General RADTRAN Input Parameters

In addition to the specific parameters discussed previously, values for several general parameters must be specified within the RADTRAN code. These general parameters define basic characteristics of the shipment and traffic and are specific to the transportation mode. The user's manual for the RADTRAN code (Neuhauser and Kanipe, 1993) contains derivations and descriptions of these parameters. Table E-9 summarizes the general RADTRAN input parameters used in the transportation risk assessment.

E.6.11 Onsite Assessment Accident Location

The onsite transportation accident consequence was estimated for a potential accident occurring on the roadway or railroad adjacent to the 300 Area at the Hanford Site. This location would maximize

Table E-9. General RADTRAN Input Parameters

Parameter	Truck	Rail
Package type	Waste-type specific	Waste-type specific
No. of crew	2	5
Distance from source to crew (m)	3	152
Average vehicular speed (km/h)		
Rural	88	64
Suburban	40	40
Urban	24	24
Stop time (h/km)	0.011	0.033
No. of people exposed while stopped	25	100
No. of people per vehicle sharing route	2	3
Population densities (persons/km^2)		
Rural	6	6
Suburban	719	719
Urban	3,861	3,861
One-way traffic count (vehicles/h)		
Rural	470	1
Suburban	780	5
Urban	2,800	5

Notes: Accident conditional probabilities are listed by severity category in Table E-6; accident release fractions are given in Table E-7.

Source: Neuhauser and Kanipe, 1993.

exposure to worker populations onsite and to the public offsite. The highest accident severity category possible for each waste type was assumed to determine the amounts of radioactive material released.

E.7 Results of Risk Assessment

This section presents results of the transportation risk assessment for each of the four types of radioactive waste considered in the PEIS. For each waste type, results are presented for the Alternatives summarized in Section E.2.2 and defined in detail in the waste type-specific chapters (Chapters 6 through 9). As stated previously, the number and location of potential treatment, storage, or disposal sites differs for each specific Alternative, and the number of Alternatives considered varies among waste types.

Although the method for risk assessment and important assumptions about assessment have been presented in detail previously, the following sections give a brief overview of the risk assessment process. This overview is intended to help readers interpret results as they are presented for each waste type.

For each waste type, the impacts of transportation are calculated in four areas: (1) collective population risks during routine conditions and accidents for each Alternative, (2) risks to MEIs during routine conditions for each Alternative, (3) consequences to individuals and populations after the most severe accidents involving release of radioactive material, and (4) onsite transportation risks. Each of these areas is described briefly.

Collective Population Risk. The collective population risk is a measure of the total risk posed to society as a whole by the Alternative being considered. For the collective population risk assessment, the persons exposed are considered as a group, without specifying individual receptors. The collective population risk is used as the primary means to compare the various Alternatives.

Collective population risks are calculated from vehicle- and cargo-related causes for routine transportation and accidents. Vehicle-related risks are independent of the shipment's cargo and include risks from vehicular exhaust emissions and traffic accidents (fatalities caused by physical trauma). Vehicle-related risks are presented in terms of estimated fatalities for each Alternative.

For radioactive material, cargo-related risk refers to the risk posed by the radioactive nature of the material. The RADTRAN 4 model is used to calculate collective population risks for each Alternative. The RADTRAN 4 calculations for population risk take into account the consequences and the probabilities of potential exposure-causing events (such as accidents). The accident risk values are referred to as "dose risk" because they incorporate the probabilities of a spectrum of accidents. The collective population risks are presented in terms of the total dose (person-rem) to workers and to members of the public for each Alternative. The collective population risks are also presented in terms of estimated fatalities from latent cancer by using the ICRP Publication 60 (ICRP, 1991) health risk conversion factors described in Section E.6.8. Other health endpoints, such as the incidence of cancer and severe genetic effects, are not explicitly presented but can be calculated by multiplying the total doses by the appropriate conversion factors given in Section E.6.8.

Maximally Exposed Individuals During Routine Conditions. During the routine transportation of radioactive waste, specific individuals close to a shipment may be exposed to radiation. For each waste type, the RISKIND model has been used to estimate risk to these individuals for a number of hypothetical exposure-causing events. The receptors include transportation crew members, inspectors, and members of the public exposed during traffic delays, while working at a service station, or living near a DOE Site. The assumptions about exposure are given in Section E.6.9. The scenarios for exposure are not meant to be exhaustive but were selected to provide a range of potential exposures.

For most individual receptors considered, doses are assessed and presented on a per-event basis. No attempt has been made to estimate the frequency of exposure-causing events, although the range of possible exposures is qualitatively discussed. However, one exception is the calculation of the dose to a hypothetical resident living near the entrance route to a treatment, storage, or disposal site. For these residents, cumulative doses are calculated on the basis of the total number of shipments entering or exiting each site for each Alternative.

Accident Consequence Assessment. The RISKIND code is used to provide a detailed assessment of the consequences of the most severe transportation-related accidents for each waste type. The RADTRAN 4 collective accident risk assessment considers the entire range of accident severities and their related probabilities, whereas the RISKIND accident consequence assessment assumes that an accident of the highest severity category (Category VIII) has occurred. The consequences, in terms of committed dose (rem) and latent cancer fatalities, are calculated for exposed populations and individuals near an accident.

For each waste type, accident consequences are calculated for a waste shipment that represents the highest potential radiological risk if an accident occurs. This "worst case" waste is identified for each waste type by screening the site-specific characteristics for radiological waste (that is, activity concentrations) developed for the PEIS, by taking into account the physical forms of the waste and relative hazards of individual radionuclides. For most waste shipments, the consequences of severe accidents would be fewer than those presented for the "worst case" waste. Separate accident consequence calculations are not performed for each case for a given waste type. The accident consequence assessment is intended to provide an estimate of the maximum potential impacts posed by a severe transportation-related accident.

Onsite Assessment. The risk assessment conducted for onsite transportation is intended to provide an estimate of the magnitude of the potential onsite transportation risk for comparison with offsite transportation risks. For the PEIS, onsite transportation is defined as transportation of waste between facilities within the boundaries of a DOE Site. Transfers of waste within a specific facility are not considered onsite shipments but are part of the normal facility operations. (Offsite transportation refers to transporting waste between distinct Sites, including parts of the routes that may be within the boundaries of the origin and destination Sites.)

For purposes of the PEIS, the onsite risk assessment has been limited to one representative Site—the Hanford Site. The Hanford Site was selected primarily because it is a relatively large Site that conducts waste management activities for all waste types. The impacts calculated for the Hanford Site are believed to be typical of other large DOE Sites and would conservatively bound the impacts expected for smaller Sites. The routine risks presented for the Hanford Site are expected to be the same among alternatives for each waste type. This is because all radioactive waste is shipped to a centrally located processing facility regardless of final treatment/disposal, onsite or offsite.

E.7.1 HIGH-LEVEL WASTE

The generation, treatment, and management of HLW and the Alternatives considered in the PEIS are described in detail in Folga et al (1995). In summary, canisters of vitrified HLW would be produced at the four DOE Sites that have historically generated and currently store HLW, and these canisters would be transported to a geologic repository for final disposal. Untreated HLW is transferred between facilities by a special pipeline system. Treated (vitrified) HLW will be stored in facilities in close

proximity to the vitrification facilities. No significant onsite transportation of HLW is assumed to occur.

Transportation risks have been calculated for four HLW alternatives summarized in Section E.2.2. The six alternative cases differ primarily in the location for interim storage of canisters before final disposal in a repository. For assessing the impacts of transportation, the PEIS assumes the location of the repository to be at the candidate site of Yucca Mountain in Nevada, the only site currently authorized by legislation for investigation.

E.7.1.1 Shipment Summary

The number of canisters of vitrified HLW ultimately shipped to a geologic repository varies from approximately 3,300 for the No Action Alternative to over 41,000 for the second case of the Centralized Alternative. The impacts of transportation have been calculated for shipping the entire estimated inventory of HLW canisters. However, the repository is expected to accept approximately 400 canisters per year when it becomes operational. Impacts have been calculated separately for all truck and rail modes of shipment.

The total number of shipments and the mileage for loaded shipments for each case are summarized in Table E-10 for truck shipments, and Table E-11 for rail shipments. For the six HLW cases, the total number of truck shipments ranges from 3,336 if the canisters from currently available storage are shipped directly to a repository (No Action Alternative) to about 41,744 if the repository opens late and all the canisters are consolidated at one Site for interim storage (Centralized 2 Alternative). For rail transportation, the corresponding numbers of shipments range from about 668 to 8,350. The total mileage for loaded shipments ranges from about 11.6 to 82.5 million km (7.2 to 51 million mi) for truck transportation and from about 2.7 to 18.3 million km (1.7 to 11.4 million mi) for rail transportation.

For purposes of comparison, within the United States for the years 1986 to 1988, the average annual reported mileage for interstate truck shipments of all commodities was approximately 45.1 billion km (28 billion mi), and for train shipments approximately 48.8 billion railcar-km (30.3 billion railcar-mi) (Saricks and Kvitek, 1994). The entire number of HLW shipments for the Centralized 2 Alternative would thus represent less than 0.2 percent of the annual amount of truck and rail transportation activity within the United States.

Table E-10. Total Population Impacts of HLW Transportation for the WM PEIS Cases: Truck Mode

Parameter	Alternative[a]						
	No Action	Decentralized	Regionalized 1	Regionalized 2	Centralized 1	Centralized 2	Onsite
Shipment summary							
Shipments	3,336	28,372	28,672	28,672	31,372	41,744	NA[b]
Mileage (10^6 mi)	7.2	35.7	36.0	36.1	39.8	51.3	NA[b]
Population impacts							
Cargo-related[c]							
Dose risk (person-rem)							
Routine crew	644	3,170	3,200	3,210	3,530	4,470	NA[b]
Routine public	855	4,290	4,330	4,340	4,770	6,080	NA[b]
Accident[d]	0.291	0.743	0.739	0.746	0.786	0.885	NA[b]
Latent cancer fatalities[e]							
Crew fatalities	0.26	1.3	1.3	1.3	1.4	1.8	NA[b]
Public fatalities	0.43	2.1	2.2	2.2	2.4	3.0	NA[b]
Vehicle-related[f]							
Emission fatalities	0.044	0.28	0.28	0.28	0.30	0.35	NA[b]
Accident fatalities	0.49	2.2	2.2	2.2	2.4	3.0	NA[b]
Total population health effects (fatalities)	1.2	5.9	6.0	6.0	6.5	8.2	NA[b]

Note: NA = not applicable.
[a] Alternative definitions are summarized in Section E.2.2 and provided in detail in Chapter 3 of the WM PEIS.
[b] By definition, no onsite HLW shipments exist at the Hanford Site.
[c] Cargo-related impacts are impacts attributable to the radioactive nature of the waste material.
[d] Dose risk is a societal risk and is the product of accident probability and accident consequence.
[e] Latent cancer fatalities are calculated by multiplying dose by the ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public.
[f] Vehicle-related impacts are impacts independent of the shipment's cargo.

E.7.1.2 Collective Population Risk Results

The results for collective risk assessment for HLW shipments are also summarized in Table E-10 for truck shipments and Table E-11 for rail shipments. The collective risk results are presented for shipment of the total estimated inventory of HLW canisters.

An examination of the results of the transportation risk assessment shows that differences in population risk among the various cases are dependent primarily on the number of shipments made and then on total shipping distances. The number of shipments and total shipping distance for each case is determined by the case definition (storage capacity, repository availability, shipment origin, and destination Sites), the site-specific waste inventories (specifically waste volume and mass, which

Table E-11. Total Population Impacts of HLW Transportation for the WM PEIS Cases: Rail Mode

Parameter	Alternative[a]						
	No Action	Decentralized	Regionalized 1	Regionalized 2	Centralized 1	Centralized 2	Onsite
Shipment summary							
Shipments	668	5,675	5,735	5,735	6,277	8,350	NA[b]
Mileage (10^6 mi)	1.65	7.94	8.03	8.03	8.78	11.4	NA[b]
Population impacts							
Cargo-related[c]							
Dose risk (person-rem)							
Routine crew	34.2	192	195	195	213	278	NA[b]
Routine public	46.1	204	206	206	222	284	NA[b]
Accident	0.00933	0.0227	0.0221	0.0228	0.0247	0.0299	NA[b]
Latent cancer fatalities[d]							
Crew fatalities	0.014	0.077	0.078	0.078	0.085	0.11	NA[b]
Public fatalities	0.023	0.10	0.10	0.10	0.11	0.14	NA[b]
Vehicle-related[e]							
Emission fatalities	0.014	0.048	0.048	0.048	0.051	0.063	NA[b]
Accident fatalities	0.0034	0.017	0.017	0.017	0.018	0.024	NA[b]
Total population health effects (fatalities)	0.054	0.24	0.24	0.24	0.26	0.34	NA[b]

Note: NA = not applicable.
[a] Alternative definitions are summarized in Section E.2.2 and provided in detail in Chapter 3 of the WM PEIS.
[b] By definition, no onsite HLW shipments exist at the Hanford Site.
[c] Cargo-related impacts are impacts attributable to the radioactive nature of the waste material.
[d] Dose risk is a societal risk and is the product of accident probability and accident consequence.
[e] Latent cancer fatalities are calculated by multiplying dose by the ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public.
[f] Vehicle-related impacts are impacts independent of the shipment's cargo.

directly determine the total number of shipments), and the route distances among all pairs of origin and destination Sites.

For truck transportation, the total estimated number of fatalities from radiological causes ranges from approximately 0.7 to 4.8. For rail transportation, the number of fatalities from radiological causes ranges from 0.037 to 0.25. In general, shipment by rail results in lower doses to crew members and the public, primarily because of the reduced number of shipments. The vehicle- and cargo-related risks are comparable for truck shipments. The cargo-related risks are generally greater than the vehicle-related risks for rail transportation.

E.7.1.3 Maximally Exposed Individual Assessment

The estimated doses during routine transportation for each individual receptor considered (see Section E.6.9 for exposure assumptions) are presented in Table E-12 on a per-event basis. The total dose for repeated exposures can be estimated by multiplying the per-event dose by the number of exposure-causing events.

The potential exists for significant individual exposures if multiple exposure-causing events occur. For example, the dose to a person stuck in traffic next to an HLW shipment for 30 minutes is estimated to be 11 mrem. If the duration of exposure were longer, the dose would rise proportionally. Therefore, conceivably, a person could receive a dose of approximately 30 to 50 mrem while stopped in traffic next to an HLW shipment. In addition, a person working at a truck service station could receive an increased dose if trucks used the same stops repeatedly. If a truck stop worker is present for 100 shipment stops (at the distance and duration given previously), the calculated dose would be approximately 30 mrem. Administrative controls could be instituted to control the location and duration of truck stops if multiple exposures were to occur routinely.

Table E-12. Estimated Routine Doses and Lifetime Risk of Fatal Cancer to MEIs From Shipments of HLW (per Exposure Event)[a]

	Dose (rem)		Lifetime Risk[c]	
Receptor[b]	Truck	Rail	Truck	Rail
Workers				
Crew member	d	d	d	d
Inspector	0.0029	0.0029	1×10^{-6}	1×10^{-6}
Rail-yard crew member	NA	0.0013	NA	5×10^{-7}
Public				
Resident	4.0×10^{-7}	4.0×10^{-7}	2×10^{-10}	2×10^{-10}
Person in traffic jam	0.011	0.011	6×10^{-6}	6×10^{-6}
Person at service station	3.1×10^{-4}	NA	2×10^{-7}	NA
Resident near rail stop	NA	1.3×10^{-5}	NA	7×10^{-9}

Note: NA = not applicable.
[a] The external dose rate is assumed to be 10 mrem/h at 2 m (6.6 ft) for all shipments.
[b] Receptor assumptions are described in Section E.6.9.
[c] Lifetime risk of fatal cancer based on ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public.
[d] The DOE administrative control level limits doses to DOE workers to 2 rem/yr.

Table E-13 summarizes for each case the potential cumulative dose to a resident living along a Site entrance route. The cumulative doses assume that a resident is present for every shipment entering or exiting a Site and is unshielded at a distance of 30 m (98 ft) from the entrance route. The maximum cumulative dose would occur near the repository, except for the Centralized 2 case, because of the large number of shipments entering the Site for all Alternatives. The maximum total dose to this resident would be approximately 11 mrem for the all-truck case and 1 mrem for the all-rail case. For the Centralized 2 case where temporary storage of all HLW occurs at Hanford, the maximum total dose to a resident would be approximately 17 mrem for the all-truck case and 3 mrem for the all-rail case. The estimated dose to a resident would be well below the annual limit of 100 mrem specified for members of the public (DOE, 1990b).

E.7.1.4 Accident Consequence Assessment

Table E-14 presents results of the accident consequence assessment for HLW. As stated previously, the results are calculated for transportation-related accidents that result in the maximum release of radioactive material. The results were calculated for SRS HLW, which was found to result in the highest accident-related doses of the four types of Site-specific HLW; however, all maximum accident-related doses for the four HLW types were within a factor of 5. The population doses are for a uniform population density within an 80-km (50-mi) radius of accidents in rural, suburban, and urban population density zones.

The location of the MEI after an accident is determined on the basis of atmospheric conditions and the buoyant characteristics of the released plume. The locations of maximum exposure are 160 m (525 ft) from the accident site for neutral conditions, and 400 m (1,312 ft) for stable conditions. The dose to the MEI is independent of the accident location. The maximum dose to an individual is approximately 60 mrem under unfavorable weather conditions, which corresponds to a lifetime fatal cancer risk of 3×10^{-4}.

E.7.1.5 Onsite Assessment Results

As defined previously, no onsite transportation of HLW will occur at the Hanford Site. Therefore, no onsite transportation impacts have been calculated for the Site.

Table E-13. Cumulative Routine Dose and Lifetime Risk to an MEI Living Along a Site Entrance Route for Shipments of HLW[a]

Alternative and Site	All Truck			All Rail		
	Total Shipments	Dose (rem)	Lifetime Risk[b]	Total Shipments	Dose (rem)	Lifetime Risk[b]
No Action						
Repository	3336	1.3×10^{-3}	7×10^{-7}	668	2.7×10^{-4}	1×10^{-7}
SRS	2286	9.1×10^{-4}	5×10^{-7}	458	1.8×10^{-4}	9×10^{-8}
Hanford	750	3.0×10^{-4}	2×10^{-7}	150	6.0×10^{-5}	3×10^{-8}
WVDP	300	1.2×10^{-4}	6×10^{-8}	60	2.4×10^{-5}	1×10^{-8}
INEL	0	0	0	0	0	0
Decentralized						
Repository	28372	1.1×10^{-2}	6×10^{-6}	5675	2.3×10^{-3}	1×10^{-6}
Hanford	15000	6.0×10^{-3}	3×10^{-6}	3000	1.2×10^{-3}	6×10^{-7}
INEL	8500	3.4×10^{-3}	2×10^{-6}	1700	6.8×10^{-4}	3×10^{-7}
SRS	4572	1.8×10^{-3}	9×10^{-7}	915	3.7×10^{-4}	2×10^{-7}
WVDP	300	1.2×10^{-4}	6×10^{-8}	60	2.4×10^{-5}	1×10^{-8}
Regionalized 1						
Repository	28372	1.1×10^{-2}	6×10^{-6}	5675	2.3×10^{-3}	1×10^{-6}
Hanford	15000	6.0×10^{-3}	3×10^{-6}	3000	1.2×10^{-3}	6×10^{-7}
INEL	8500	3.4×10^{-3}	2×10^{-6}	1700	6.8×10^{-4}	3×10^{-7}
SRS	5172	2.1×10^{-3}	1×10^{-6}	1034	4.1×10^{-4}	2×10^{-7}
WVDP	300	1.2×10^{-4}	6×10^{-8}	60	2.4×10^{-5}	1×10^{-8}
Regionalized 2						
Repository	28372	1.1×10^{-2}	6×10^{-6}	5675	2.3×10^{-3}	1×10^{-6}
Hanford	15600	6.2×10^{-3}	3×10^{-6}	3120	1.2×10^{-3}	6×10^{-7}
INEL	8500	3.4×10^{-3}	2×10^{-6}	1700	6.8×10^{-4}	3×10^{-7}
SRS	4572	1.8×10^{-3}	9×10^{-7}	915	3.7×10^{-4}	2×10^{-7}
WVDP	300	1.2×10^{-4}	6×10^{-8}	60	2.4×10^{-5}	1×10^{-8}
Centralized 1						
Repository	28372	1.1×10^{-2}	6×10^{-6}	5675	2.3×10^{-3}	1×10^{-6}
Hanford	21000	8.4×10^{-3}	4×10^{-6}	4200	1.7×10^{-3}	8×10^{-7}
INEL	8500	3.4×10^{-3}	2×10^{-6}	1700	6.8×10^{-4}	3×10^{-7}
SRS	4572	1.8×10^{-3}	9×10^{-7}	915	3.7×10^{-4}	2×10^{-7}
WVDP	300	1.2×10^{-4}	6×10^{-8}	60	2.4×10^{-5}	1×10^{-8}
Centralized 2						
Hanford	41744	1.7×10^{-2}	8×10^{-6}	8350	3.3×10^{-3}	2×10^{-6}
Repository	28372	1.1×10^{-2}	6×10^{-6}	5675	2.3×10^{-3}	1×10^{-6}
INEL	8500	3.4×10^{-3}	2×10^{-6}	1700	6.8×10^{-4}	3×10^{-7}
SRS	4572	1.8×10^{-3}	9×10^{-7}	915	3.7×10^{-4}	2×10^{-7}
WVDP	300	1.2×10^{-4}	6×10^{-8}	60	2.4×10^{-5}	1×10^{-8}

[a] The external dose rate is assumed to be 10 mrem/h at 2 m (6.6 ft). The resident is assumed to be present for all shipments that either enter or exit the Site. Shipments are assumed to pass at a distance of 30 m (98 ft) and an average speed of 24 km/h (15 mi/h).

[b] Lifetime risk of fatal cancer based on ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public.

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Table E-14. Estimated Consequences for the Most Severe Accidents Involving Shipments of HLW[a,b]

	Neutral Conditions[c]				Stable Conditions[d]			
	Population[e]		MEI[f]		Population[e]		MEI[f]	
Mode and Accident Location	Dose (person-rem)	Risk (cancer fatalities)	Dose (rem)	Risk (cancer fatality)	Dose (person-rem)	Risk (cancer fatalities)	Dose (rem)	Risk (cancer fatality)
Truck								
Urban	4.2	2×10^{-3}	3.4×10^{-3}	1.7×10^{-6}	34	1.7×10^{-2}	1.2×10^{-2}	6×10^{-6}
Suburban	0.78	4×10^{-4}	3.4×10^{-3}	1.7×10^{-6}	6.2	3.1×10^{-3}	1.2×10^{-2}	6×10^{-6}
Rural	0.016	8×10^{-6}	3.4×10^{-3}	1.7×10^{-6}	0.13	6.5×10^{-5}	1.2×10^{-2}	6×10^{-6}
Rail								
Urban	21	1×10^{-2}	1.7×10^{-2}	8.5×10^{-6}	170	8.5×10^{-2}	6×10^{-2}	3×10^{-5}
Suburban	3.9	2×10^{-3}	1.7×10^{-2}	8.5×10^{-6}	31	1.6×10^{-2}	6×10^{-2}	3×10^{-5}
Rural	0.080	4×10^{-5}	1.7×10^{-2}	8.5×10^{-6}	0.65	3.3×10^{-4}	6×10^{-2}	3×10^{-5}

[a] The most severe accidents correspond to the highest NUREG-0170 accident severity category (Category VIII) (NRC, 1977a). Results are presented for HLW from SRS.
[b] Buoyant plume rise resulting from fire for a severe accident was included in the exposure model. One HLW canister is assumed to be breached in a truck accident; five canisters are assumed to be equally breached in a rail accident.
[c] Neutral weather conditions result in moderate dispersion and dilution of the released plume. Neutral conditions were considered to be Pasquill Stability Class D with a windspeed of 4 m/s (9 mi/h). Neutral conditions occur approximately 50 percent of the time in the United States.
[d] Stable weather conditions result in minimal dispersion and dilution of the released plume and thus are unfavorable. Stable conditions were taken to be Pasquill Stability Class F with a windspeed of 1 m/s (2.2 mi/h). Stable conditions occur approximately one-third of the time in the United States.
[e] Populations extend at a uniform population density to a radius of 80 km (50 mi) from the accident site. Population exposure pathways include acute inhalation; acute cloudshine; groundshine; resuspended inhalation; resuspended cloudshine; and ingestion of food, including initially contaminated food (rural only). No decontamination or mitigative actions are taken.
f The MEI is assumed to be at the location of maximum exposure. The locations of maximum exposure would be 160 m (525 ft) from the accident site under neutral atmospheric conditions and 400 m (1,312 ft) under stable atmospheric conditions. Individual exposure pathways include acute inhalation, acute cloudshine, and groundshine during passage of the plume. No ingested dose is considered.

E.7.2 LOW-LEVEL WASTE

The projected rate of LLW generation for each Site, the waste characteristics, the potential treatments, and the Alternatives considered in the PEIS are described in detail in the LLW technical report (Goyette, 1995). Transportation risks have been calculated for the 14 LLW Alternatives summarized in Section E.2.2. The cases range from decentralized to centralized approaches to TSD. The number of disposal Sites varies from 16 Sites for decentralized disposal to 1 Site for centralized disposal. Options for treatment also vary from decentralized to centralized approaches.

The PEIS considers current inventories of LLW plus 20 years of generation for all DOE Sites. All impacts are calculated as totals for the entire inventory of waste under consideration. The average annual risk can be estimated by dividing the summarized results by the duration of the shipping campaigns. For the No Action Alternative, shipments would be distributed uniformly over a 20-year period; however, for all other Alternatives, shipments would occur uniformly over a 10-year period, with the assumption of a 10-year period to build TSD facilities. These timeframes are consistent with the assumptions used in the facility assessments for estimating throughputs.

E.7.2.1 Shipment Summary

The total number of shipments and the mileage for loaded shipments for each LLW case are summarized in Table E-15 for truck shipments, and Table E-16 for rail shipments. The estimated number of shipments and the total mileage for the various Alternatives span a wide range. The total number of truck shipments ranges from approximately 24,420 for the Decentralized Alternative to about 264,000 shipments for the Centralized 4 Alternative. For rail transportation, the corresponding numbers of shipments range from 9,210 to 102,100. The total mileage for loaded shipments ranges from 9.0 to 906 million km (5.57 to 563 million mi) for truck transportation and from 3.4 to 360 million km (2.1 to 224 million mi) for rail transportation. The average annual number of shipments and mileage can be estimated by dividing the total results by a shipping duration of either 10 or 20 years.

For comparison, within the United States for the years 1986 to 1988, the average annual reported mileage for interstate truck shipments of all commodities was approximately 45 billion km (28 billion mi), and for train shipments approximately 48.8 billion railcar-km (30.3 billion railcar-mi) (Saricks and Kvitek, 1994). The estimated annual LLW shipments for the maximum transportation Alternative would represents approximately 0.2 percent of the annual truck and rail transportation activity within the United States.

E.7.2.2 Collective Population Risk Results

The results for the collective risk assessment for the 10 LLW Alternatives are also summarized in Table E-15 for truck shipments, and Table E-16 for rail shipments. The results for collective risk are

Table E–15. Total Population Impacts of Transportation of Current LLW Inventories Plus 20 Years of LLW Generation: Truck Mode

Impact	Alternative[a]														
	No Action	Decentralized	Regionalized 1	Regionalized 2	Regionalized 3	Regionalized 4	Regionalized 5	Regionalized 6	Regionalized 7	Centralized 1	Centralized 2	Centralized 3	Centralized 4	Centralized 5	On-site[b]
Shipment summary															
Shipments	87,360	24,420	25,800	25,880	84,200	87,390	92,200	174,390	188,930	242,730	257,270	250,020	264,060	241,540	11,640
Mileage (10^6 mi)	166	5.57	9.31	9.19	38.1	36.9	63.8	124	125	563	505	530	478	560	0.27
Population impacts															
Cargo-related[c]															
Dose risk (person-rem)															
Routine crew	4,690	225	343	338	1,210	1,190	1,900	3,870	3,890	15,800	14,500	14,900	13,700	15,700	10.1
Routine public	5,620	241	362	357	1,340	1,310	2,180	4,350	4,410	18,700	17,200	17,700	16,300	18,700	0.224
Accident[d]	2.45	0.129	0.648	0.648	1.52	2.13	344	233	205	580	563	580	567	580	NA
Latent cancer fatalities[e]															
Crew fatalities	1.9	0.090	0.1	0.1	0.5	0.48	0.8	1.5	1.6	6.3	5.8	6.0	5.5	6.3	0.004
Public fatalities	2.7	0.12	0.2	0.2	0.7	0.66	1.1	2.3	2.2	9.7	8.6	9.1	8.4	9.3	0.0001
Vehicle-related[f]															
Emission fatalities	1.0	0.12	0.1	0.1	0.2	0.22	0.3	0.67	0.8	2.4	2.9	2.2	2.8	2.4	NA
Accident fatalities	10.8	0.30	0.5	0.5	2.6	2.5	4.4	8.7	9.0	35	35.1	33	34	35.0	NA
Total population health effects (fatalities)	16.4	0.63	0.9	0.9	4.0	3.9	6.6	13	13.6	53	52.4	50	51	53.0	NA

Note: NA = not applicable.
[a] Alternative definitions are summarized in Section E.2.2 and provided in detail in Chapter 3 of the PEIS.
[b] Onsite impacts are calculated for the Hanford Site.
[c] Cargo-related impacts are impacts attributable to the radioactive nature of the waste material.
[d] Dose risk is a societal risk and is the product of accident probability and accident consequence.
[e] Latent cancer fatalities are calculated by multiplying dose by the ICRP Publication 60 health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public (ICRP, 1991).
[f] Vehicle-related impacts are impacts independent of the cargo in the shipment.

Table E–16. Total Population Impacts of Transportation of Current LLW Inventories Plus 20 Years of LLW Generation: Rail Mode

Impact	Alternative[a]														
	No Action	Decentralized	Regionalized 1	Regionalized 2	Regionalized 3	Regionalized 4	Regionalized 5	Regionalized 6	Regionalized 7	Centralized 1	Centralized 2	Centralized 3	Centralized 4	Centralized 5	On-site[b]
Shipment summary															
Shipments	33,420	9,210	9,740	9,900	31,850	33,460	35,430	66,040	71,480	91,440	96,880	96,710	102,100	90,980	4,360
Mileage (10^6 mi)	69.9	2.09	3.74	3.78	17.2	16.6	25.3	51.4	54.4	224	219	218	212	223	0.122
Population impacts															
Cargo-related[c]															
Dose risk (person-rem)															
Routine crew	388	35.3	43.7	44.2	163	166	208	405	433	1,190	1,190	1,190	1,180	1,190	1.38
Routine public	849	104	135	136	408	368	470	820	845	2,340	2,340	2,310	2,310	2,330	0
Accident[d]	1.03	0.0841	0.162	0.162	0.626	0.886	23.9	44.0	25.0	114	90.9	114	91.6	113	NA
Latent cancer fatalities[e]															
Crew fatalities	0.15	0.014	0.02	0.02	0.07	0.067	0.08	0.16	0.17	0.48	0.47	0.48	0.47	0.47	5.52×10
Public fatalities	0.43	0.052	0.07	0.07	0.21	0.18	0.23	0.43	0.42	1.2	1.20	1.1	1.2	1.20	0
Vehicle-related[f]															
Emission fatalities	0.78	0.10	0.13	0.13	0.32	0.23	0.35	0.47	0.47	1.8	1.8	1.7	1.8	1.8	NA
Accident fatalities	0.15	0.0044	0.0078	0.0079	0.036	0.035	0.053	0.11	0.11	0.47	0.46	0.46	0.45	0.47	NA
Total population health effects (fatalities)	1.5	0.17	0.23	0.23	0.64	0.51	0.71	1.2	1.2	4.0	3.9	3.7	3.9	3.9	NA

Note: NA = not applicable.
[a] Alternative definitions are summarized in Section E.2.2 and provided in detail in Chapter 3 of the PEIS.
[b] Onsite impacts are calculated for the Hanford Site.
[c] Cargo-related impacts are impacts attributable to the radioactive nature of the waste material.
[d] Dose risk is a societal risk and is the product of accident probability and accident consequence.
[e] Latent cancer fatalities are calculated by multiplying dose by the ICRP Publication 60 health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public (ICRP, 1991).
[f] Vehicle-related impacts are impacts independent of the cargo in the shipment.

presented for shipment of the current inventories plus the estimated generation of LLW for a period of 20 years.

Examination of the results of the transportation risk assessment shows that differences in population risk among the various cases are primarily dependent on total shipping distances. Thus, in general, centralized options predictably show larger transportation risks than regionalized or decentralized approaches because the centralized options involve greater transportation distances. The total shipping distance for each Alternative is determined by the definition of the case (shipment origin and destination Sites), Site-specific waste inventories (specifically waste volume and mass, which directly determine the total number of shipments), packaging assumptions, and route distances among all pairs of origin and destination Sites.

For truck transportation, the total estimated number of fatalities from radiological causes ranges from approximately 0.2 to 16. For rail transportation, fatalities from radiological causes range from 0.07 to 1.7. Shipment by rail results in lower doses to crew members and the public, primarily because of the reduced number of shipments involved. In general, for LLW shipments, the vehicle-related risks are greater than the associated cargo-related risks.

E.7.2.3 Maximally Exposed Individual Assessment

The estimated doses during routine transportation for each of the individual receptors considered (see Section E.6.9 for exposure assumptions) are presented in Table E–17 on a per-event basis. The total dose for repeated exposures can be estimated by multiplying the per-event dose by the number of exposures.

As noted previously for HLW shipments, the potential exists for significant individual exposures if multiple exposure-causing events occur during LLW shipments; for instance, the dose to a person caught in a traffic jam for 30 minutes next to a shipment is estimated to be 0.5 mrem. If the exposure is longer, the dose would rise proportionally. Therefore, it is conceivable that a person could receive a dose of between 2 to 10 mrem while stopped in traffic next to an LLW shipment. In addition, a person working at a truck service station could receive an increased dose if trucks were to use the same stops repeatedly. If a truck-stop worker is present for 100 shipment stops (at the distance and duration given previously), the estimated dose is approximately 2 mrem. Administrative controls could be

Table E-17. Estimated Routine Doses and Lifetime Risk of Fatal Cancer to MEIs From Shipments of LLW (per Exposure Event)[a]

Receptor[b]	Dose (rem)		Lifetime Risk[c]	
	Truck	Rail	Truck	Rail
Workers				
Crew member	d	d	d	d
Inspector	1.5×10^{-4}	1.5×10^{-4}	6×10^{-8}	6×10^{-8}
Rail-yard crew member	NA	7.9×10^{-5}	NA	3×10^{-8}
Public				
Resident	1.6×10^{-8}	1.6×10^{-8}	8×10^{-12}	8×10^{-12}
Person in traffic jam	5.0×10^{-4}	5.0×10^{-4}	3×10^{-7}	3×10^{-7}
Person at service station	2.1×10^{-5}	NA	1×10^{-8}	NA
Resident near rail stop	NA	1.1×10^{-6}	NA	6×10^{-10}

Note: NA = not applicable.
[a] The external dose rate is assumed to be 10 mrem/h at 2 m (6.6 ft) for all shipments.
[b] Receptor assumptions are described in Section E.6.9.
[c] Lifetime risk of fatal cancer based on ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public.
[d] The DOE administrative control level limits doses to DOE workers to 2 rem/yr.

instituted to control the location and duration of truck stops if multiple exposures were to happen routinely. The probability of multiple exposures increases as the amount of waste transportation increases.

The potential cumulative dose to a resident living along a Site entrance route is summarized in Table E-18 for the LLW Alternatives. Doses were calculated for all DOE Sites in each case; however, only the five Sites sending or receiving the most shipments have been included in Table E-18. The cumulative doses assume that a resident is present for every shipment entering and exiting a Site and is unshielded at a distance of 30 m (98 ft) from the roadway. The maximum cumulative dose would occur near centralized facilities because of the large number of shipments entering a single Site; for instance, for the Centralized 2 Alternative, the maximum dose to a resident living near the NTS would be approximately 4 mrem for the all-truck case and 2 mrem for the all-rail case. The annual dose can be estimated by assuming that shipments would occur over a 20-year period for the No Action Alternative and over a 10-year period for all other cases. The estimated annual dose to a resident would be well below the annual limit of 100 mrem specified for members of the public (DOE, 1990b).

Table E-18. Cumulative Dose and Lifetime Risk to an MEI Living Along a Site Entrance Route for Shipments of LLW (Current Inventories Plus 20 Years of Generation)[a]

Alternative and Site[b]	All Truck			All Rail		
	Total Shipments	Dose (rem)	Lifetime Risk[c]	Total Shipments	Dose (rem)	Lifetime Risk[c]
No Action						
NTS	69,960	1.1×10^{-3}	6×10^{-7}	26,740	4.3×10^{-4}	2×10^{-7}
PORTS	33,440	5.4×10^{-4}	3×10^{-7}	12,740	2.1×10^{-4}	1×10^{-7}
Hanford	17,340	2.8×10^{-4}	1×10^{-7}	6,640	1.1×10^{-4}	6×10^{-8}
Pantex	13,740	2.2×10^{-4}	1×10^{-7}	5,440	8.8×10^{-5}	4×10^{-8}
RMI	7,300	1.2×10^{-4}	6×10^{-8}	2,740	4.4×10^{-5}	2×10^{-8}
Decentralized						
PORTS	12,800	2.1×10^{-4}	1×10^{-7}	4,770	7.7×10^{-5}	4×10^{-8}
RMI	7,680	1.2×10^{-4}	6×10^{-8}	2,870	4.6×10^{-5}	2×10^{-8}
BNL	6,790	1.1×10^{-4}	6×10^{-8}	2,580	4.2×10^{-5}	2×10^{-8}
KAPL-S	6,780	1.1×10^{-4}	6×10^{-8}	2,570	4.1×10^{-5}	2×10^{-8}
Mound	5,120	8.2×10^{-5}	4×10^{-8}	1,900	3.1×10^{-5}	2×10^{-8}
Regionalized 1						
PORTS	24,820	4.0×10^{-4}	2×10^{-7}	9,330	1.5×10^{-4}	8×10^{-8}
RMI	7,680	1.2×10^{-4}	6×10^{-8}	2,870	4.6×10^{-5}	2×10^{-8}
KAPL-S	6,780	1.1×10^{-4}	6×10^{-8}	2,570	4.1×10^{-5}	2×10^{-8}
Mound	5,120	8.2×10^{-5}	4×10^{-8}	1,900	3.1×10^{-5}	2×10^{-8}
Bettis	3,730	6.0×10^{-5}	3×10^{-8}	1,410	2.3×10^{-5}	1×10^{-8}
Regionalized 2						
PORTS	24,380	3.9×10^{-4}	2×10^{-7}	9,260	1.5×10^{-4}	8×10^{-8}
RMI	7,610	1.2×10^{-4}	6×10^{-8}	2,850	4.6×10^{-5}	2×10^{-8}
KAPL-S	6,670	1.1×10^{-4}	5×10^{-8}	2,560	4.1×10^{-5}	2×10^{-8}
Mound	5,080	8.2×10^{-5}	4×10^{-8}	1,910	3.1×10^{-5}	2×10^{-8}
Bettis	3,660	5.9×10^{-5}	3×10^{-8}	1,400	2.3×10^{-5}	1×10^{-8}
Regionalized 3						
ORR	64,590	1.0×10^{-3}	5×10^{-7}	24,470	3.9×10^{-4}	2×10^{-7}
PORTS	33,440	5.4×10^{-4}	3×10^{-7}	12,740	2.1×10^{-4}	1×10^{-7}
LANL	18,400	3.0×10^{-4}	2×10^{-7}	6,910	1.1×10^{-4}	6×10^{-8}
Pantex	14,500	2.3×10^{-4}	1×10^{-7}	5,440	8.8×10^{-5}	4×10^{-8}
RMI	7,680	1.2×10^{-4}	6×10^{-8}	2,870	4.6×10^{-5}	2×10^{-8}
Regionalized 4						
ORR	58,210	9.4×10^{-4}	5×10^{-7}	22,310	3.6×10^{-4}	2×10^{-7}
PORTS	47,610	7.7×10^{-4}	4×10^{-7}	18,410	3.0×10^{-4}	2×10^{-7}
LANL	17,860	2.9×10^{-4}	1×10^{-7}	6,740	1.1×10^{-4}	5×10^{-8}
Pantex	14,180	2.3×10^{-4}	1×10^{-7}	5,370	8.6×10^{-5}	4×10^{-8}
RMI	7,520	1.2×10^{-4}	6×10^{-8}	2,860	4.6×10^{-5}	2×10^{-8}

Table E-18. Cumulative Dose and Lifetime Risk to an MEI Living Along a Site Entrance Route for Shipments of LLW (Current Inventories Plus 20 Years of Generation)[a]—Continued

Alternative and Site[b]	All Truck			All Rail		
	Total Shipments	Dose (rem)	Lifetime Risk[c]	Total Shipments	Dose (rem)	Lifetime Risk[c]
Regionalized 5						
ORR	63,430	1.0×10^{-3}	5×10^{-7}	24,170	3.9×10^{-4}	2×10^{-7}
PORTS	32,500	5.2×10^{-4}	3×10^{-7}	12,500	2.0×10^{-4}	1×10^{-7}
INEL	25,620	4.1×10^{-4}	2×10^{-7}	10,020	1.6×10^{-4}	8×10^{-8}
Pantex	13,830	2.2×10^{-4}	1×10^{-7}	5,380	8.7×10^{-5}	4×10^{-8}
LANL	11,750	1.9×10^{-4}	1×10^{-7}	4,640	7.5×10^{-5}	4×10^{-8}
Regionalized 6						
SRS	130,030	2.1×10^{-3}	1×10^{-6}	49,340	7.9×10^{-4}	4×10^{-7}
ORR	65,420	1.1×10^{-3}	5×10^{-7}	24,860	4.0×10^{-4}	2×10^{-7}
Hanford	44,360	7.1×10^{-4}	4×10^{-7}	16,700	2.7×10^{-4}	1×10^{-7}
PORTS	33,440	5.4×10^{-4}	3×10^{-7}	12,740	2.1×10^{-4}	1×10^{-7}
Pantex	14,500	2.3×10^{-4}	1×10^{-7}	5,440	8.8×10^{-5}	4×10^{-8}
Regionalized 7						
SRS	130,030	2.1×10^{-3}	1×10^{-6}	49,340	7.9×10^{-4}	4×10^{-7}
ORR	65,420	1.1×10^{-3}	5×10^{-7}	24,860	4.0×10^{-4}	2×10^{-7}
NTS	58,900	9.5×10^{-4}	5×10^{-7}	22,140	3.6×10^{-4}	2×10^{-7}
PORTS	33,440	5.4×10^{-4}	3×10^{-7}	12,740	2.1×10^{-4}	1×10^{-7}
Hanford	14,540	2.3×10^{-4}	1×10^{-7}	5,440	8.8×10^{-5}	4×10^{-8}
Centralized 1						
Hanford	242,730	3.9×10^{-3}	2×10^{-6}	91,440	1.5×10^{-3}	7×10^{-7}
SRS	68,340	1.1×10^{-3}	6×10^{-7}	25,400	4.1×10^{-4}	2×10^{-7}
ORR	65,420	1.1×10^{-3}	5×10^{-7}	24,860	4.0×10^{-4}	2×10^{-7}
PORTS	33,440	5.4×10^{-4}	3×10^{-7}	12,740	2.1×10^{-4}	1×10^{-7}
Pantex	14,500	2.3×10^{-4}	1×10^{-7}	5,440	8.8×10^{-5}	4×10^{-8}
Centralized 2						
NTS	257,270	4.1×10^{-3}	2×10^{-6}	96,880	1.6×10^{-3}	8×10^{-7}
SRS	68,340	1.1×10^{-3}	6×10^{-7}	25,400	4.1×10^{-4}	2×10^{-7}
ORR	65,420	1.1×10^{-3}	5×10^{-7}	24,860	4.0×10^{-4}	2×10^{-7}
PORTS	33,440	5.4×10^{-4}	3×10^{-7}	12,740	2.1×10^{-4}	1×10^{-7}
Hanford	14,540	2.3×10^{-4}	1×10^{-7}	5,440	8.8×10^{-5}	4×10^{-8}
Centralized 3						
Hanford	225,660	3.6×10^{-3}	2×10^{-6}	87,240	1.4×10^{-3}	7×10^{-7}
SRS	67,520	1.1×10^{-3}	5×10^{-7}	25,230	4.1×10^{-4}	2×10^{-7}
ORR	61,250	9.9×10^{-4}	5×10^{-7}	24,470	3.9×10^{-4}	2×10^{-7}
PORTS	47,440	7.6×10^{-4}	4×10^{-7}	18,350	3.0×10^{-4}	2×10^{-7}
LANL	36,640	5.9×10^{-4}	3×10^{-7}	14,400	2.3×10^{-4}	1×10^{-7}

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Table E-18. Cumulative Dose and Lifetime Risk to an MEI Living Along a Site Entrance Route for Shipments of LLW (Current Inventories Plus 20 Years of Generation)[a]—Continued

Alternative and Site[b]	All Truck			All Rail		
	Total Shipments	Dose (rem)	Lifetime Risk[c]	Total Shipments	Dose (rem)	Lifetime Risk[c]
Centralized 4						
NTS	239,350	3.9×10^{-3}	2×10^{-6}	92,470	1.5×10^{-3}	7×10^{-7}
SRS	67,520	1.1×10^{-3}	5×10^{-7}	25,230	4.1×10^{-4}	2×10^{-7}
ORR	61,250	9.9×10^{-4}	5×10^{-7}	24,470	3.9×10^{-4}	2×10^{-7}
PORTS	47,440	7.6×10^{-4}	4×10^{-7}	18,350	3.0×10^{-4}	2×10^{-7}
LANL	36,640	5.9×10^{-4}	3×10^{-7}	14,400	2.3×10^{-4}	1×10^{-7}
Centralized 5						
Hanford	241,540	3.9×10^{-3}	2×10^{-6}	90,980	1.5×10^{-3}	7×10^{-7}
SRS	68,540	1.1×10^{-3}	6×10^{-7}	25,320	4.1×10^{-4}	2×10^{-7}
ORR	65,840	1.1×10^{-3}	5×10^{-7}	24,890	4.0×10^{-4}	2×10^{-7}
PORTS	32,500	5.2×10^{-4}	3×10^{-7}	12,500	2.0×10^{-4}	1×10^{-7}
Pantex	14,180	2.3×10^{-4}	1×10^{-7}	5,370	8.6×10^{-5}	4×10^{-8}

[a] The external dose rate is assumed to be 1 mrem/h at 1 m (3.3 ft) for all shipments. The resident is assumed to be present for all shipments that either enter or exit the Site. Shipments are assumed to pass at a distance of 30 m (98 ft) and an average speed of 24 km/h (15 mi/h).
[b] For each Alternative, only the five Sites sending or receiving the most shipments are reported. All other Sites have MEI doses less than those presented here.
[c] Lifetime risk of fatal cancer based on ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public.

E.7.2.4 Accident Consequence Assessment

For the accident consequence assessment, the waste characteristics for each Site were screened to determine the waste with the highest potential radiological consequences if a release were to occur. The LLW from the Argonne National Laboratory-West (ANL-W) Site results in the highest transportation accident doses. The doses were highest primarily because the LLW from ANL-W contains a significant amount of cobalt-60, nearly 7,000 Ci per shipment. To comply with regulations in 10 CFR 71 for Type A packagings, the material would have to be shipped in many packages. In practice, such quantities likely would be shipped in Type B packages; however, for purposes of assessment, the ANL-W source term was used to conservatively estimate the impacts of potential LLW accidents.

As stated previously, the accident consequences were calculated for transportation-related accidents that result in the maximum release of radioactive material (accident severity Category VIII). The accident

consequence results are presented in Table E-19. The population doses are for a uniform population density within an 80-km (50-mi) radius of accidents occurring in rural, suburban, and urban population density zones.

The location of the MEI after an accident is determined on the basis of atmospheric conditions and buoyant characteristics of the released plume. The locations of maximum exposure from the accident site are 160 m (525 ft) for neutral conditions and 400 m (1,312 ft) for stable conditions.

Table E-19. Estimated Consequences for the Most Severe Accidents Involving Shipments of LLW [a,b]

	Neutral Conditions[c]				Stable Conditions[d]			
	Population[e]		MEI[f]		Population[e]		MEI[f]	
Mode and Accident Location	**Dose (person-rem)**	**Risk (cancer fatalities)**	**Dose (rem)**	**Risk (cancer fatality)**	**Dose (person-rem)**	**Risk (cancer fatalities)**	**Dose (rem)**	**Risk (cancer fatality)**
Truck								
Urban	8,300	4.2	0.77	3.9×10^{-4}	67,000	34	2.6	1.3×10^{-3}
Suburban	1,600	0.8	0.77	3.9×10^{-4}	12,000	6	2.6	1.3×10^{-3}
Rural	15	0.008	0.77	3.9×10^{-4}	120	0.06	2.6	1.3×10^{-3}
Rail								
Urban	22,000	11	2.1	1.3×10^{-3}	180,000	90	7.0	3.5×10^{-3}
Suburban	4,200	2.1	2.1	1.3×10^{-3}	33,000	17	7.0	3.5×10^{-3}
Rural	41	0.02	2.1	1.3×10^{-3}	320	0.16	7.0	3.5×10^{-3}

[a] The most severe accidents correspond to the highest NUREG-0170 accident severity category (Category VIII) (NRC, 1977a). Results are reported for LLW from ANL-W, which was found to result in the highest potential accident doses.
[b] Buoyant plume rise resulting from fire for a severe accident was included in the exposure model.
[c] Neutral weather conditions result in moderate dispersion and dilution of the released plume. Neutral conditions were taken to be Pasquill Stability Class D with a windspeed of 4 m/s (9 mi/h). Neutral conditions occur approximately 50 percent of the time in the United States.
[d] Stable weather conditions result in minimal dispersion and dilution of the released plume and are thus unfavorable. Stable conditions were taken to be Pasquill Stability Class F with a windspeed of 1 m/s (2.2 mi/h). Stable conditions occur approximately one-third of the time in the United States.
[e] Populations extend at a uniform population density to a radius of 80 km (50 mi) from the accident site. Population exposure pathways include acute inhalation; acute cloudshine; groundshine; resuspended inhalation; resuspended cloudshine; and ingestion of food, including initially contaminated food (rural only). No decontamination or mitigative actions are taken.
[f] The MEI is assumed to be at the location of maximum exposure. The locations of maximum exposure would be 160 m (525 ft) and 400 m (1,312 ft) from the accident site under neutral and stable atmospheric conditions, respectively. Individual exposure pathways include acute inhalation, acute cloudshine, and groundshine during passage of the plume. No ingested dose is considered.

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The dose to the MEI is independent of the accident location. The maximum dose to an individual (approximately 7 rem for a rail accident under unfavorable weather conditions) has a potential lifetime fatal cancer risk of 4×10^{-3}.

The accident consequence results for LLW from ANL-W should be considered extremely conservative for most LLW shipments for a number of reasons. First, the LLW from ANL-W represents less than 1 percent by volume of the total LLW generated annually within DOE. Only about two truck shipments would be required each year to transport ANL-W waste to an offsite facility for treatment, storage, or disposal. Therefore, it is unlikely that a severe LLW accident would involve the LLW from ANL-W. Second, the accident dose results for LLW from ANL-W are at least a factor of 10 greater than those for LLW from other Sites, primarily because of the cobalt-60 content of the ANL-W waste. The "average" accident consequences would be much less than those presented here.

E.7.2.5 Onsite Assessment Results

The onsite risks for LLW transportation at the Hanford Site are summarized in Table E–15 for truck transportation and in Table E–16 for rail transportation. The risks presented for the transportation crew include the dose to workers in areas along the shipping route. The total dose to workers close to the route is generally much less than the dose to the actual crew members involved in transporting the waste. Risks calculated for the public include persons sharing the transportation route with waste shipments. The MEI for routine conditions, besides crew members, was considered to be a guard at a facility gate or checkpoint along the route who is exposed to each shipment for 1 minute at a distance of 5 m (16.4 ft). The total dose to the guard for all shipments is estimated to be 30 mrem. Overall, the routine onsite shipment risks are much less than the offsite shipment risks for all cases considered.

In addition, the consequences of an onsite accident at the Hanford Site are summarized in Table E–20. For the accident consequence assessment, the characteristics of LLW from the Hanford Site were used. The MEI is located at the position where maximum impacts would occur, similar to the offsite accident consequence assessment. An exposure of 2 hours was assumed for the population of onsite workers after an accident. The impacts on the offsite population were calculated by using the population distribution in the vicinity of the Hanford Site and by assuming a 1-year exposure duration.

Table E–20. Results of Onsite Accident Consequence Assessment for the Hanford Site

Waste and Transport Mode	Onsite Population		Offsite Population		MEI	
	Neutral Conditions	Stable Conditions	Neutral Conditions	Stable Conditions	Neutral Conditions	Stable Conditions
Dose (person-rem)						
LLW						
Truck	0.076	0.26	0.90	7.7	0.0077	0.026
Rail	0.20	0.69	2.4	21	0.021	0.070
CH-TRUW						
Truck	10	36	6.0	52	0.25	0.84
Rail	21	70	12	100	0.50	1.7
RH-TRUW						
Truck	2.1	7.1	1.2	11	0.050	0.17
Rail	4.1	14	2.4	21	0.10	0.34
LLMW						
Truck	4.5	16	8.1	69	0.11	0.36
Rail	12	40	21	180	0.28	0.93
Risk (latent cancer fatalities)						
LLW						
Truck	3.0×10^{-5}	1.0×10^{-4}	4.5×10^{-4}	3.8×10^{-3}	3.9×10^{-6}	1.3×10^{-5}
Rail	8.1×10^{-5}	2.8×10^{-4}	1.2×10^{-3}	1.0×10^{-2}	1.0×10^{-5}	3.5×10^{-5}
CH-TRUW						
Truck	4.2×10^{-3}	1.4×10^{-2}	3.0×10^{-3}	2.6×10^{-2}	1.3×10^{-4}	4.2×10^{-4}
Rail	8.2×10^{-3}	2.8×10^{-2}	5.9×10^{-3}	5.2×10^{-2}	2.5×10^{-4}	8.3×10^{-4}
RH-TRUW						
Truck	8.2×10^{-4}	2.8×10^{-3}	6.0×10^{-4}	5.3×10^{-3}	2.5×10^{-5}	8.4×10^{-5}
Rail	1.6×10^{-3}	5.6×10^{-3}	1.2×10^{-3}	1.1×10^{-2}	5.0×10^{-5}	1.7×10^{-4}
LLMW						
Truck	1.8×10^{-3}	6.2×10^{-3}	4.0×10^{-3}	3.5×10^{-2}	5.3×10^{-5}	1.8×10^{-4}
Rail	4.7×10^{-3}	1.6×10^{-2}	1.1×10^{-2}	9.0×10^{-2}	1.4×10^{-4}	4.6×10^{-4}

E.7.3 TRANSURANIC WASTE

The projected rate for TRUW generation for each Site, the waste characteristics, the potential treatments, and the cases considered in the PEIS are described in detail in the TRUW technical report (Hong et al., 1995). Transportation risks have been calculated for five TRUW alternative cases summarized in Section E.2.2 (1 of the 6 Alternatives does not involve waste transportation). The Alternatives range from decentralized to centralized approaches to treatment and storage before final geologic disposal. The No Action Alternative does not involve transport of waste. The other Alternatives each have CH-TRUW and RH-TRUW components. The transportation assessment assumes that all TRUW will ultimately be shipped to WIPP for disposal. The WM PEIS considers current inventories of TRUW plus 20 years of TRUW generation for all DOE Sites. All impacts are

calculated as totals for the entire waste inventory under consideration. The average annual risk can be estimated by dividing the summarized results by the duration of the shipping campaigns. For purposes of the PEIS, to estimate the sizes of potential facilities needed for treatment, the assumption has been made that waste would be shipped over a 10-year period. Previous assessments have assumed that TRUW would be shipped to WIPP over a 20-year period (DOE, 1990b).

E.7.3.1 Shipment Summary

The total number of shipments and the mileage for loaded shipments for each TRUW Alternative are summarized in Table E–21 for truck shipments and Table E–22 for rail shipments. The total truck shipments range from approximately 18,640 to 23,900. For rail transportation, the corresponding numbers range from 9,360 to 12,010 shipments. The total distance for loaded shipments ranges from 55 to 69 million km (34 to 43 million mi) for truck transportation and from 26 to 34 million km (16 to 21 million mi) for rail transportation. The average annual number of shipments and mileage can be estimated by dividing the total results by a shipping duration of either 10 or 20 years.

For comparison, within the United States for the years 1986 to 1988, the average annual reported mileage for interstate truck shipments of all commodities was approximately 45 billion km (28 billion mi), and for rail shipments approximately 48.8 billion railcar-km (30.3 billion railcar-mi) (Saricks and Kvitek, 1994). The maximum estimated annual TRUW shipments would represent much less than 0.1 percent of the annual truck and rail transportation activity within the United States.

E.7.3.2 Collective Population Risk Results

The results for collective risk assessment for the TRUW Alternatives are also summarized in Table E–21 for truck shipments and Table E–22 for rail shipments. The collective risk results are presented for shipment of the current TRUW inventories plus the estimated generation of TRUW for a period of 20 years.

Examination of the results of the transportation risk assessment shows that differences in population risk among the various cases are dependent primarily on total shipping distances. The total shipping distance for each Alternative is determined by the definition of the case (shipment origin and destination Sites), Site-specific waste inventories (specifically waste volume and mass, which directly determine

Table E-21. Total Population Impacts of Transportation of Current TRUW Inventories Plus 20 Years of TRUW Generation: Truck Mode

Impact	Alternative[a]						
	No Action	Decentralized	Regionalized 1	Regionalized 2	Regionalized 3	Centralized	Onsite[b]
Shipment summary							
Shipments	0	23,900	21,680	18,640	20,600	21,640	206
Mileage (10^6 mi)	-	42.4	38.3	34.0	37.2	38.7	0.0047
Population impacts							
Cargo-related[c]							
Dose risk (person-rem)							
Routine crew	-	3,650	3,260	2,888	3,160	3,310	11
Routine public	-	3,870	3,360	2,940	3,310	3,490	0.56
Accident[d]	-	9.80	8.98	8.98	11.8	8.93	NA
Latent cancer fatalities[e]							
Crew fatalities	-	1.5	1.3	1.2	1.3	1.3	0.0044
Public fatalities	-	1.9	1.7	1.5	1.7	1.7	0.00028
Vehicle-related[f]							
Emission fatalities	-	0.22	0.19	0.18	0.19	0.20	NA
Accident fatalities	-	3.0	2.7	2.4	2.6	2.7	NA
Total population health effects (fatalities)	-	6.6	5.9	5.2	5.7	6.0	NA

Note: NA = not applicable.
[a] Alternative definitions are summarized in Section E.2.2 and provided in detail in Chapter 3 of the PEIS.
[b] Onsite impacts are calculated for the Hanford Site.
[c] Cargo-related impacts are impacts attributable to the radioactive nature of the waste material.
[d] Dose risk is a societal risk and is the product of accident probability and accident consequence.
[e] Latent cancer fatalities are calculated by multiplying dose by the ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public.
[f] Vehicle-related impacts are independent of the shipment's cargo.

the total number of shipments), packaging assumptions, and the route distances among all pairs of origin-and-destination Sites.

The total estimated number of fatalities from radiological causes ranges from approximately 2.7 to 3.4 for truck shipments. For rail transportation, fatalities from radiological causes range from 0.67 to 0.90. Shipment by the rail mode results in lower doses to crew members and the public, primarily because of the reduced number of shipments involved. In general, for TRUW shipments, the vehicle-related risks are comparable to the associated cargo-related risks.

Table E–22. Total Population Impacts of Transportation of Current TRUW Inventories Plus 20 Years of TRUW Generation: Rail Mode

Impact	Alternative[a]						
	No Action	Decentralized	Regionalized 1	Regionalized 2	Regionalized 3	Centralized	Onsite[b]
Shipment summary							
Shipments	0	12,010	10,890	9,360	10,340	10,870	104
Mileage (10^6 mi)	-	20.3	18.2	15.8	17.4	18.4	0.0029
Population impacts							
Cargo-related[c]							
Dose risk (person-rem)							
Routine crew	-	836	756	656	718	759	4.8
Routine public	-	1,134	978	821	907	1,011	0
Accident[d]	-	0.777	0.770	0.773	0.844	0.768	NA
Latent cancer fatalities[e]							
Crew fatalities	-	0.33	0.30	0.26	0.28	0.30	0.0019
Public fatalities	-	0.57	0.49	0.41	0.46	0.51	0
Vehicle-related[f]							
Emission fatalities	-	0.10	0.10	0.080	0.080	0.10	NA
Accident fatalities	-	0.043	0.037	0.033	0.036	0.039	NA
Total population health effects (fatalities)	-	1.0	0.93	0.78	0.86	0.95	NA

Note: NA = not applicable.
[a] Alternative definitions are summarized in Section E.2.2 and provided in detail in Chapter 3 of the PEIS.
[b] Onsite impacts are calculated for the Hanford Site.
[c] Cargo-related impacts are impacts attributable to the radioactive nature of the waste material.
[d] Dose risk is a societal risk and is the product of accident probability and accident consequence.
[e] Latent cancer fatalities are calculated by multiplying dose by the ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public.
[f] Vehicle-related impacts are independent of the shipment's cargo.

E.7.3.3 Maximally Exposed Individual Assessment

The estimated doses during routine transportation for each individual receptor considered (see Section E.6.9 for exposure assumptions) are presented in Table E–23 for CH-TRUW, and in Table E–24 for RH-TRUW. Th total dose for repeated exposures can be estimated by multiplying the per-event dose by the number of exposure.

Except for doses to crew members, all doses are presented for single exposures. Note that the potential exists for significant individual exposures if multiple exposure-causing events occur. For example, the

Table E-23. Estimated Routine Doses and Lifetime Risk of Fatal Cancer to MEIs From Shipments of CH-TRUW (per Exposure Event)[a]

Receptor[b]	Dose (rem)		Lifetime Risk[c]	
	Truck	Rail	Truck	Rail
Workers				
Crew member	d	d	d	d
Inspector	0.0014	0.0014	6×10^{-7}	6×10^{-7}
Rail-yard crew member	NA	0.0015	NA	6×10^{-7}
Public				
Resident	1.5×10^{-7}	3.0×10^{-7}	8×10^{-11}	2×10^{-10}
Person in traffic jam	0.0047	0.0093	2×10^{-6}	5×10^{-6}
Person at service station	1.9×10^{-4}	NA	1×10^{-7}	NA
Resident near rail stop	NA	2.1×10^{-5}	NA	1×10^{-8}

Note: NA = not applicable.
[a] The dose rate is assumed to be 3 mrem/h at 1 m (3.3 ft) from each package.
[b] Receptor assumptions are described in Section E.6.9.
[c] Lifetime risk of fatal cancer based on ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public.
[d] The DOE administrative control level limits doses to DOE workers to 2 rem/yr.

Table E-24. Estimated Routine Doses and Lifetime Risk of Fatal Cancer to MEIs From Shipments of RH-TRUW (per Exposure Event)[a]

Receptor[b]	Dose (rem)		Lifetime Risk[c]	
	Truck	Rail	Truck	Rail
Workers				
Crew member	d	d	d	d
Inspector	0.0010	0.0010	4×10^{-7}	4×10^{-7}
Rail-yard crew member	NA	0.0011	NA	4×10^{-7}
Public				
Resident	1.1×10^{-7}	2.3×10^{-7}	6×10^{-11}	1×10^{-10}
Person in traffic jam	0.0036	0.0071	2×10^{-6}	4×10^{-6}
Person at service station	1.5×10^{-4}	NA	8×10^{-8}	NA
Resident near rail stop	NA	1.5×10^{-5}	NA	8×10^{-9}

Note: NA = not applicable.
[a] Dose rate is assumed to be 7 mrem/h at 1 m (3.3 ft) from each package.
[b] Receptor assumptions are described in Section E.6.9.
[c] Lifetime risk of fatal cancer based on ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, 5×10^{-4} for the public.
[d] The DOE administrative control level limits doses to DOE workers to 2 rem/yr.

dose to a person stopped in traffic next to a truck shipment of CH-TRUW for 30 minutes is estimated to be 5 mrem; if the exposure duration were longer, the dose would rise proportionally. Therefore, it is conceivable that a person could receive a dose of approximately 10 to 20 mrem while stopped in traffic next to a TRUW shipment. In addition, a person working at a truck service station could receive an increased dose if trucks used the same stops repeatedly. If a truck stop worker were present for 100 CH-TRUW shipment stops (at the distance and duration given previously), the estimated dose would be approximately 20 mrem. Administrative controls could be instituted to control the location and duration of truck stops if multiple exposures were to happen routinely. The probability of multiple exposures increases as the amount of waste transportation increases.

The cumulative dose to a resident living along a Site entrance route is summarized in Table E–25 for each TRUW Alternative. Note that each alternative involves both contact- and remote-handled shipments. Although doses were calculated for all DOE Sites storing or generating TRUW, only data for the five Sites sending or receiving the most shipments have been provided for each case in Table E–25. The cumulative doses assume that an unshielded resident is present at a distance of 30 m (98 ft) from the roadway for every shipment entering or exiting a Site. In almost all cases, the maximum cumulative dose would occur near the WIPP disposal Site. If all CH-TRUW and RH-TRUW were shipped to WIPP, the maximum dose to a resident would be less than 4 mrem for both truck and rail cases. The truck and rail doses are similar because the same number of packages would be shipped for each mode. The annual dose can be estimated by assuming that shipments would occur over either a 10- or 20-year period. The annual dose to a resident would be well below the annual limit of 100 mrem specified for members of the public through DOE orders (DOE, 1990b), as well as comparable NRC limits (10 CFR 20).

E.7.3.4 Accident Consequence Assessment

For the accident consequence assessment, the characteristics of contact- and remote-handled waste for each Site were screened to determine the waste with the highest potential radiological consequences if a release were to occur during an accident. For CH-TRUW, waste shipments from LANL were found to result in the highest potential transportation accident doses. For RH-TRUW, shipments from the Hanford Site were found to result in the highest potential accident doses. The accident consequence results are presented in Table E–26 for contact-handled shipments and Table E–27 for remote-handled shipments. The population doses are for a uniform population density within an 80-km (50-mi) radius of accidents occurring in rural, suburban, and urban population density zones.

Table E-25. Cumulative Dose and Lifetime Risk to an MEI Living Along a Site Entrance Route for Shipments of TRUW (Current Inventories Plus 20 Years of Generation)[a]

Alternative and Site[b]	All Truck			All Rail		
	Total Shipments	Dose (rem)	Lifetime Risk[c]	Total Shipments	Dose (rem)	Lifetime Risk[c]
Decentralized						
WIPP	23,860	3.6×10^{-3}	2×10^{-6}	11,970	3.6×10^{-3}	2×10^{-6}
Hanford	10,260	1.5×10^{-3}	8×10^{-7}	5,140	1.5×10^{-3}	8×10^{-7}
INEL	5,970	8.9×10^{-4}	5×10^{-7}	2,990	8.9×10^{-4}	5×10^{-7}
SRS	2,370	3.5×10^{-4}	2×10^{-7}	1,190	3.6×10^{-4}	2×10^{-7}
ORR	1,880	2.8×10^{-4}	1×10^{-7}	940	2.8×10^{-4}	1×10^{-7}
Regionalized 1						
WIPP	20,080	3.0×10^{-3}	2×10^{-6}	10,060	3.0×10^{-3}	2×10^{-6}
Hanford	10,430	1.6×10^{-3}	8×10^{-7}	5,220	1.6×10^{-3}	8×10^{-7}
INEL	4,900	7.3×10^{-4}	4×10^{-7}	2,460	7.4×10^{-4}	4×10^{-7}
ORR	2,440	3.6×10^{-4}	2×10^{-7}	1,230	3.7×10^{-4}	2×10^{-7}
SRS	1,240	1.8×10^{-4}	9×10^{-8}	630	1.9×10^{-4}	9×10^{-8}
Regionalized 2						
WIPP	17,040	2.6×10^{-3}	1×10^{-6}	8,530	2.6×10^{-3}	1×10^{-6}
Hanford	11,830	1.8×10^{-3}	9×10^{-7}	5,930	1.8×10^{-3}	9×10^{-7}
INEL	4,250	6.4×10^{-4}	4×10^{-7}	2,130	6.4×10^{-4}	4×10^{-7}
ORR	990	1.5×10^{-4}	8×10^{-8}	500	1.5×10^{-4}	8×10^{-8}
LANL	930	1.4×10^{-4}	7×10^{-8}	470	1.4×10^{-4}	7×10^{-8}
Regionalized 3						
WIPP	17,030	2.6×10^{-3}	1×10^{-6}	8,520	2.6×10^{-3}	1×10^{-6}
Hanford	11,830	1.8×10^{-3}	9×10^{-7}	5,930	1.8×10^{-3}	9×10^{-7}
INEL	7,610	1.1×10^{-3}	6×10^{-7}	3,820	1.1×10^{-3}	6×10^{-7}
LANL	1,250	1.9×10^{-4}	1×10^{-7}	630	1.9×10^{-4}	1×10^{-7}
ORR	990	1.5×10^{-4}	8×10^{-8}	500	1.5×10^{-4}	8×10^{-8}
Centralized						
WIPP	20,500	3.1×10^{-3}	2×10^{-6}	10,290	3.1×10^{-3}	2×10^{-6}
Hanford	11,610	1.7×10^{-3}	9×10^{-7}	5,820	1.7×10^{-3}	9×10^{-7}
INEL	5,180	7.7×10^{-4}	5×10^{-7}	2,600	7.8×10^{-4}	5×10^{-7}
SRS	2,080	3.1×10^{-4}	2×10^{-7}	1,040	3.1×10^{-4}	2×10^{-7}
LANL	1,250	1.9×10^{-4}	1×10^{-7}	630	1.9×10^{-4}	1×10^{-7}

[a] The external dose rates are assumed to be 3 mrem/h at 1 m (3.3 ft) for CH-TRUW, and 7 mrem/h for RH-TRUW shipments. The resident is assumed to be present for all shipments that enter or exit the Site. Shipments are assumed to pass at a distance of 30 m (98 ft) and an average speed of 24 km/h (15 mi/h).

[b] For each Alternative, only the five Sites sending or receiving the most shipments are reported. All other Sites have MEI doses less than those presented here.

[c] Lifetime risk of fatal cancer based on ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers and 5×10^{-4} for the public.

Table E-26. Estimated Consequences for the Most Severe Accidents Involving Shipments of CH-TRUW [a,b]

Mode and Accident Location	Neutral Conditions[c]				Stable Conditions[d]			
	Population[e]		MEI[f]		Population[e]		MEI[f]	
	Dose (person-rem)	Risk (cancer fatalities)	Dose (rem)	Risk (cancer fatality)	Dose (person-rem)	Risk (cancer fatalities)	Dose (rem)	Risk (cancer fatality)
Truck								
Urban	4,000	2	3.5	1.8×10^{-3}	32,000	16	12	6×10^{-3}
Suburban	740	0.37	3.5	1.8×10^{-3}	5,900	3	12	6×10^{-3}
Rural	6.5	0.003	3.5	1.8×10^{-3}	52	0.03	12	6×10^{-3}
Rail								
Urban	7,900	4	7.1	3.6×10^{-3}	63,000	32	24	1.2×10^{-2}
Suburban	1,500	0.75	7.1	3.6×10^{-3}	12,000	6	24	1.2×10^{-2}
Rural	13	0.007	7.1	3.6×10^{-3}	100	0.05	24	1.2×10^{-2}

[a] The most severe accidents correspond to the highest NUREG-0170 accident severity category (Category VIII) (NRC, 1977a). Results are reported for CH-TRUW from LANL.
[b] Buoyant plume rise resulting from fire for a severe accident was included in the exposure model. Three TRUPACT-IIs are assumed to be breached in a truck accident; six TRUPACT-IIs are assumed to be equally breached in a rail accident.
[c] Neutral weather conditions result in moderate dispersion and dilution of the released plume. Neutral conditions were taken to be Pasquill Stability Class D with a windspeed of 4 m/s (9 mi/h). Neutral conditions occur approximately 50 percent of the time in the United States.
[d] Stable weather conditions result in minimal dispersion and dilution of the released plume and are thus unfavorable. Stable conditions were taken to be Pasquill Stability Class F with a windspeed of 1 m/s (2.2 mi/h). Stable conditions occur approximately one-third of the time in the United States.
[e] Populations extend at a uniform population density to a radius of 80 km (50 mi) from the accident site. Population exposure pathways include acute inhalation; acute cloudshine; groundshine; resuspended inhalation; resuspended cloudshine; and ingestion of food, including initially contaminated food (rural only). No decontamination or mitigative actions are taken.
[f] The MEI is assumed to be at the location of maximum exposure. The locations of maximum exposure would be 160 m (525 ft) from the accident site under neutral atmospheric conditions, and 400 m (1,312 ft) for stable atmospheric conditions. Individual exposure pathways include acute inhalation, acute cloudshine, and groundshine during passage of the plume. No ingested dose is considered.

The location of the MEI after an accident is determined on the basis of atmospheric conditions and buoyant characteristics of the released plume. The locations of maximum exposure are 160 m (525 ft) from the accident site for neutral conditions, and 400 m (1,312 ft) from the accident site for stable conditions. The dose to the MEI is independent of the accident location. The maximum dose to an individual (approximately 24 rem for a rail accident under unfavorable weather conditions) corresponds to a potential lifetime fatal cancer risk of 1×10^{-2}.

Table E-27. Estimated Consequences for the Most Severe Accidents Involving Shipments of RH-TRUW [a,b]

Mode and Accident Location	Neutral Conditions[c]				Stable Conditions[d]			
	Population[e]		MEI[f]		Population[e]		MEI[f]	
	Dose (person-rem)	Risk (cancer fatalities)	Dose (rem)	Risk (cancer fatality)	Dose (person-rem)	Risk (cancer fatalities)	Dose (rem)	Risk (cancer fatality)
Truck								
Urban	60	3.0×10^{-2}	0.051	2.6×10^{-5}	480	2.4×10^{-1}	0.17	8.5×10^{-5}
Suburban	11	5.5×10^{-3}	0.051	2.6×10^{-5}	89	4.5×10^{-2}	0.17	8.5×10^{-5}
Rural	0.10	5.0×10^{-3}	0.051	2.6×10^{-5}	0.83	4.2×10^{-4}	0.17	8.5×10^{-5}
Rail								
Urban	120	6×10^{-2}	0.10	5.0×10^{-5}	950	4.8×10^{-1}	0.34	1.7×10^{-4}
Suburban	22	1.1×10^{-2}	0.10	5.0×10^{-5}	180	9.0×10^{-2}	0.34	1.7×10^{-4}
Rural	0.21	1.1×10^{-4}	0.10	5.0×10^{-5}	1.7	8.5×10^{-4}	0.34	1.7×10^{-4}

[a] The most severe accidents correspond to the highest NUREG-0170 accident severity category (Category VIII) (NRC, 1977a). Results are reported for RH-TRUW from the Hanford Site.
[b] Buoyant plume rise resulting from fire for a severe accident was included in the exposure model. One NuPac 72 B is assumed to be breached in a truck accident; two NuPac 72Bs are assumed to be equally breached in a rail accident.
[c] Neutral weather conditions result in moderate dispersion and dilution of the released plume. Neutral conditions were taken to be Pasquill Stability Class D with a windspeed of 4 m/s (9 mi/h). Neutral conditions occur approximately 50 percent of the time in the United States.
[d] Stable weather conditions result in minimal dispersion and dilution of the released plume and are thus unfavorable. Stable conditions were taken to be Pasquill Stability Class F with a windspeed of 1 m/s (2.2 mi/h). Stable conditions occur approximately one-third of the time in the United States.
[e] Populations extend at a uniform population density to a radius of 80 km (50 mi) from the accident site. Population exposure pathways include acute inhalation; acute cloudshine; groundshine; resuspended inhalation; resuspended cloudshine; and ingestion of food, including initially contaminated food (rural only). No decontamination or mitigative actions are taken.
[f] The MEI is assumed to be at the location of maximum exposure. The locations of maximum exposure would be 160 m (525 ft) and from the accident site under neutral atmospheric conditions, and 400 m (1,312 ft) for stable atmospheric conditions. Individual exposure pathways include acute inhalation, acute cloudshine, and groundshine during passage of the plume. No ingested dose is considered.

E.7.3.5 Onsite Assessment Results

The onsite risks for TRUW transportation at the Hanford Site are summarized in Table E-21 for trucks and Table E-22 for rail. The risks presented for the transportation crew include the dose to workers in areas along the shipping route. The total dose to workers adjacent to the route is generally much less than the dose to the crew members involved in transporting the waste. Risks calculated for the public include persons sharing the transportation route with waste shipments. The MEI for routine conditions, besides crew members, was considered to be a guard at a facility gate or checkpoint along the route exposed to each shipment for 1 minute at a distance of 5 m (16.4 ft). The total dose to the guard from

all shipments is estimated to be 61 mrem. Overall, the routine onsite shipment risks are much lower than the offsite shipment risks for all cases considered.

The consequences of an onsite accident at the Hanford Site are summarized in Table E–20. For the accident consequence assessment, characteristics of CH-TRUW and RH-TRUW from the Hanford Site were used. The MEI is located at the position where maximum impacts would occur, similar to the offsite accident consequence assessment. An exposure of 2 hours was assumed for the population of onsite workers after an accident. Impacts on the offsite population were calculated by using the population distribution near the Hanford Site and by assuming a 1-year exposure duration.

E.7.4 Low-Level Mixed Waste

The projected rate of LLMW generation for each Site, the waste characteristics, the potential treatments, and the cases considered in the PEIS are described in detail in Wilkins et al. (1995). Transportation risks have been calculated for the LLMW Alternatives summarized in Section E.2.2 (the No Action Alternative does not involve transportation of LLMW). The cases range from decentralized to centralized approaches to TSD. The number of disposal Sites varies from 16 Sites for decentralized disposal to 1 Site for centralized disposal. Options for treatment also vary from decentralized to centralized approaches.

The PEIS considers current inventories of LLMW plus 20 years of generation for all DOE Sites. All impacts are calculated as totals for the entire inventory of waste under consideration. The average annual risk can be estimated by dividing the summarized results by the duration of the shipping campaigns. For all alternatives, shipments would occur uniformly over a 10-year period, with the assumption of a 10-year period to build TSD facilities. These timeframes are consistent with the assumptions used in the facility assessments for estimating throughputs.

E.7.4.1 Shipment Summary

The total number of shipments and the mileage for loaded shipments for each LLMW Alternative are summarized in Table E–28 for truck shipments, and Table E–29 for rail shipments. The estimated number of shipments and the total mileage for the various cases span a wide range. The total number

Table E–28. Total Population Impacts of Transportation of Current LLMW Inventories Plus 20 Years of LLMW Generation: Truck Mode

Impact	Alternative[a]						
	Decentralized	Regionalized 1	Regionalized 2	Regionalized 3	Regionalized 4	Centralized	Onsite[b]
Shipment summary							
Shipments	490	1,820	5,560	10,990	4,250	7,520	1,720
Mileage (10^6 mi)	0.23	0.59	2.57	14.9	2.70	13.5	0.051
Population impacts							
Cargo-related[c]							
Dose risk (person-rem)							
Routine crew	7.68	20.4	80.3	429	79.9	374	1.49
Routine public	9.15	23.1	92.6	513	93.4	447	0.033
Accident[d]	0.858	2.23	15.4	26.0	16.0	148	NA
Latent cancer fatalities[e]							
Crew fatalities	0.0030	0.0083	0.032	0.17	0.031	0.15	0.00060
Public fatalities	0.0050	0.013	0.053	0.27	0.055	0.29	1.72×10^{-5}
Vehicle-related[f]							
Emission fatalities	0.0042	0.0085	0.024	0.10	0.017	0.054	NA
Accident fatalities	0.017	0.038	0.19	1.0	0.19	0.83	NA
Total fatalities	0.029	0.068	0.30	1.5	0.29	1.3	NA

Note: NA = not applicable.
[a] Alternative definitions are summarized in Section E.2.2 and provided in detail in Chapter 3 of the PEIS.
[b] Onsite impacts are calculated for the Hanford Site.
[c] Cargo-related impacts are impacts attributable to the radioactive nature of the waste material.
[d] Dose risk is a societal risk and is the product of accident probability and accident consequence.
[e] Latent cancer fatalities are calculated by multiplying dose by the ICRP Publication 60 health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers, and 5×10^{-4} for the public (ICRP, 1991).
[f] Vehicle-related impacts are impacts independent of the cargo in the shipment.

of truck shipments ranges from approximately 490 for the Decentralized Alternative to about 11,000 shipments for the Regionalized 3 Alternative. For rail transportation, the corresponding numbers of shipments range from 360 to 4,540. The total mileage for loaded shipments ranges from 0.37 to 24 million km (0.23 to 15 million mi) for truck transportation and from 0.34 to 11 million km (0.21 to 6.8 million mi) for rail transportation. The average annual number of shipments and mileage can be estimated by dividing the total results by the shipping duration which is assumed to be 10 years in the WM PEIS.

For comparison, within the United States for the years 1986 to 1988, the average annual reported mileage for interstate truck shipments of all commodities was approximately 45 billion km (28 billion mi), and for train shipments approximately 48.8 billion railcar-km (30.3 billion railcar-mi) (Saricks and Kvitek, 1994). The estimated annual LLMW shipments for the maximum transportation Alternative would represent less than 0.1 percent of the annual truck and rail transportation activity within the United States.

Table E–29. Total Population Impacts of Transportation of Current LLMW Inventories Plus 20 Years of LLMW Generation: Rail Mode

Impact	Alternative[a]						
	Decentralized	Regionalized 1	Regionalized 2	Regionalized 3	Regionalized 4	Centralized	Onsite[b]
Shipment summary							
Shipments	360	1,030	2,490	4,540	2,050	3,340	660
Mileage (10^6 mi)	0.21	0.48	1.37	6.76	1.52	6.46	0.026
Population impacts							
Cargo-related[c]							
Dose risk (person-rem)							
Routine crew	1.93	4.98	12.9	41.3	12.2	36.6	0.206
Routine public	5.11	13.7	29.1	75.8	28.1	69.3	0.0024
Accident[d]	0.257	0.596	2.18	4.61	2.61	27.6	NA
Latent cancer fatalities[e]							
Crew fatalities	0.00077	0.0020	0.0052	0.017	0.0049	0.015	8.3×10^{-5}
Public fatalities	0.0027	0.0072	0.015	0.040	0.015	0.049	9.6×10^{-7}
Vehicle-related[f]							
Emission fatalities	0.0047	0.013	0.023	0.055	0.024	0.053	NA
Accident fatalities	0.00045	0.0010	0.0028	0.014	0.0032	0.014	NA
Total fatalities	0.0086	0.023	0.046	0.13	0.047	0.13	NA

Note: NA = not applicable.
[a] Alternative definitions are summarized in Section E.2.2 and provided in detail in Chapter 3 of the PEIS.
[b] Onsite impacts are calculated for the Hanford Site.
[c] Cargo-related impacts are impacts attributable to the radioactive nature of the waste material.
[d] Dose risk is a societal risk and is the product of accident probability and accident consequence.
[e] Latent cancer fatalities are calculated by multiplying dose by the ICRP Publication 60 health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers and 5×10^{-4} for the public (ICRP, 1991).
[f] Vehicle-related impacts are impacts independent of the cargo in the shipment.

E.7.4.2 Collective Population Risk Results

The results for the collective risk assessment for the LLMW Alternatives are also summarized in Table E–28 for truck shipments, and Table E–29 for rail shipments. The results for collective risk are presented for shipment of the current inventories plus the estimated generation of LLMW for a period of 20 years.

Examination of the results of the transportation risk assessment shows that differences in population risk among the various cases are primarily dependent on total shipping distances. Thus, in general, centralized options predictably show larger transportation risks than regionalized or decentralized approaches because the centralized options involve greater transportation distances. The total shipping distance for each Alternative is determined by the definition of the case (shipment origin and destination Sites), Site-specific waste inventories (specifically waste volume and mass, which directly determine

the total number of shipments), packaging assumptions, and route distances among all pairs of origin and destination Sites.

For truck transportation, the total estimated number of fatalities from radiological causes ranges from approximately 0.008 to 0.5. For rail transportation, fatalities from radiological causes range from 0.003 to 0.06. Shipment by rail results in lower doses to crew members and the public, primarily because of the reduced number of shipments involved. In general, for LLMW shipments, the vehicle-related risks are greater than the associated cargo-related risks.

E.7.4.3 Maximally Exposed Individual Assessment

The estimated doses during routine transportation for each of the individual receptors considered (see Section E.6.9 for exposure assumptions) are presented in Table E–30 on a per-event basis. The total dose for repeated exposures can be estimated by multiplying the per-event dose by the number of exposures.

As noted previously for HLW and LLW shipments, the potential exists for significant individual exposures if multiple exposure-causing events occur during LLMW shipments; for instance, the dose to a person caught in a traffic jam for 30 minutes next to a shipment is estimated to be 0.5 mrem. If the exposure is longer, the dose would rise proportionally. Therefore, it is conceivable that a person could receive a dose of between 2 to 10 mrem while stopped in traffic next to an LLMW shipment. In addition, a person working at a truck service station could receive an increased dose if trucks were to use the same stops repeatedly. If a truck-stop worker is present for 100 shipment stops (at the distance and duration given previously), the estimated dose is approximately 2 mrem. Administrative controls could be instituted to control the location and duration of truck stops if multiple exposures were to happen routinely. The probability of multiple exposures increases as the amount of waste transportation increases.

The potential cumulative dose to a resident living along a Site entrance route is summarized in Table E–31 for the LLMW Alternatives. Doses were calculated for all DOE Sites for each case; however, only the five Sites sending or receiving the most shipments have been included in Table E–31. The cumulative doses assume that a resident is present for every shipment entering and exiting a Site and is unshielded at a distance of 30 m (98 ft) from the roadway. The maximum

Table E-30. Estimated Routine Doses and Lifetime Risk of Fatal Cancer to MEIs From Shipments of LLMW (per Exposure Event)[a]

Receptor[b]	Dose (rem)		Lifetime Risk[c]	
	Truck	Rail	Truck	Rail
Workers				
Crew member	d	d	d	d
Inspector	1.5×10^{-4}	1.5×10^{-4}	6×10^{-8}	6×10^{-8}
Rail-yard crew member	NA	7.9×10^{-5}	NA	3×10^{-8}
Public				
Resident	1.6×10^{-8}	1.6×10^{-8}	8×10^{-12}	8×10^{-12}
Person in traffic jam	5.0×10^{-4}	5.0×10^{-4}	3×10^{-7}	3×10^{-7}
Person at service station	2.1×10^{-5}	NA	1×10^{-8}	NA
Resident near rail stop	NA	1.1×10^{-6}	NA	6×10^{-10}

Note: NA = not applicable.
[a] Dose rate is assumed to be 1 mrem/h at 1 m (3.3 ft) from an LLMW shipment.
[b] Receptor assumptions are described in Section E.6.9.
[c] Lifetime risk of fatal cancer based on ICRP Publication 60 (ICRP, 1991) health risk conversion factors of 4×10^{-4} fatal cancers per person-rem for workers and 5×10^{-4} for the public (ICRP, 1991).
[d] The DOE administrative control level limits doses to DOE workers to 2 rem/yr.

cumulative dose would occur near regionalized or centralized facilities because of the large number of shipments entering a small number of sites; for instance, for the Regionalized 3 Alternative, the maximum dose to a resident living near the NTS would be approximately 0.2 mrem for the all-truck case and 0.06 mrem for the all-rail case. The annual dose can be estimated by assuming that shipments would occur over a 10-year period for all Alternatives. The estimated annual dose to a resident would be well below the annual limit of 100 mrem specified for members of the public through DOE Orders (DOE, 1990b), as well as comparable NRC limits (10 CFR 20).

E.7.4.4 Accident Consequence Assessment

As stated previously, the accident consequences were calculated for transportation-related accidents that result in the maximum release of radioactive material (accident severity Category VIII). For these accidents, the assumptions were that all of the material in the shipment would be released from its packaging, that 10% would be entrained as an aerosol, and that 5% of the aerosol would be respirable.

Table E-31 Cumulative Dose and Lifetime Risk to MEI Living Along a Site Entrance Route for WM LLMW Shipments (Current Inventories plus 20 Years of Generation)[a]

WM Case and Site[b]	All Truck			All Rail		
	Total Shipments	Dose (rem)	Risk (Fatal Cancer)[c]	Total Shipments	Dose (rem)	Risk (Fatal Cancer)[c]
Case 2a						
LLNL	250	4.0E-06	2E-09	120	1.9E-06	1E-09
NTS	110	1.8E-06	9E-10	50	8.1E-07	4E-10
ETEC	110	1.8E-06	9E-10	40	6.4E-07	3E-10
WVDP	100	1.6E-06	8E-10	100	1.6E-06	8E-10
SRS	90	1.4E-06	7E-10	90	1.4E-06	7E-10
Case 4						
FEMP	1,060	1.7E-05	9E-09	410	6.6E-06	3E-09
PORTS	820	1.3E-05	7E-09	440	7.1E-06	4E-09
ANL-E	450	7.2E-06	4E-09	180	2.9E-06	1E-09
LLNL	310	5.0E-06	3E-09	180	2.9E-06	1E-09
NTS	120	1.9E-06	1E-09	60	9.7E-07	5E-10
Case 7						
LANL	2,610	4.2E-05	2E-08	1,020	1.6E-05	8E-09
RFETS	2,560	4.1E-05	2E-08	980	1.6E-05	8E-09
PORTS	2,260	3.6E-05	2E-08	960	1.5E-05	8E-09
ORR	1,660	2.7E-05	1E-08	650	1.0E-05	5E-09
ANL-E	450	7.2E-06	4E-09	180	2.9E-06	1E-09
Case 10a						
NTS	9,650	1.6E-04	8E-08	3,700	6.0E-05	3E-08
RFETS	2,560	4.1E-05	2E-08	980	1.6E-05	8E-09
PORTS	2,260	3.6E-05	2E-08	960	1.5E-05	8E-09
ORR	2,100	3.4E-05	2E-08	790	1.3E-05	6E-09
Hanford	1,690	2.7E-05	1E-08	710	1.1E-05	6E-09
Case 15						
RFETS	1,990	3.2E-05	2E-08	740	1.2E-05	6E-09
INEL	1,740	2.8E-05	1E-08	760	1.2E-05	6E-09
ORR	1,480	2.4E-05	1E-08	740	1.2E-05	6E-09
LANL	830	1.3E-05	7E-09	350	5.6E-06	3E-09
PORTS	650	1.0E-05	5E-09	260	4.2E-06	2E-09
Case 17						
Hanford	7,520	1.2E-04	6E-08	3,340	5.4E-05	3E-08
RFETS	1,990	3.2E-05	2E-08	740	1.2E-05	6E-09
ORR	1,970	3.2E-05	2E-08	740	1.2E-05	6E-09
INEL	700	1.1E-05	6E-09	290	4.7E-06	2E-09
PORTS	650	1.0E-05	5E-09	260	4.2E-06	2E-09

[a] The external dose rate is assumed to be 1 mrem/h at 1 m (3.3 ft) for all shipments. The resident is assumed to be present for all shipments that enter or exit the site. Shipments are assumed to pass at a distance of 30 m (98 ft) and an average speed of 24 km/h (15 mph).

[b] For each Alternative, only the five sites sending or receiving the most shipments are reported. All other sites have MEI doses less than those presented here.

[c] The risk of fatal cancer is calculated by using the ICRP Publication 60 (ICRP, 1991) health risk conversion factor of 5E-04 fatal cancers per person-rem for members of the public.

During screening, the LLMW from the Paducah Gaseous Diffusion Plant (PGDP) was found to result in the highest transportation accident doses for the most severe accidents. The accident consequence results from RISKIND for LLMW shipments are presented in Table E-32. The population doses are

9513387.2430

Table E-32 Estimated Consequences for the Most Severe Accidents Involving Shipments of WM LLMW[a,b]

Mode and Accident Location	Neutral Conditions[c]				Stable Conditions[d]			
	Population[e]		MEI[f]		Population[e]		MEI[f]	
	Dose (person-rem)	Risk (Cancer Fatalities)	Dose (rem)	Risk (Cancer Fatality)	Dose (person-rem)	Risk (Cancer Fatalities)	Dose (rem)	Risk (Cancer Fatality)
Truck								
Urban	6E+02	3E-01	5.3E-01	2.7E-04	4.75E+03	2E+00	1.8E+00	9.0E-04
Suburban	1.1E+02	6E-02	5.3E-01	2.7E-04	8.85E+02	4E-01	1.8E+00	9.0E-04
Rural	1.0E+00	5E-04	5.3E-01	2.7E-04	7.5E+00	4E-03	1.8E+00	9.0E-04
Rail								
Urban	1.62E+03	8E-01	1.4E+00	7.0E-04	1.283E+04	6E+00	4.8E+00	2.4E-03
Suburban	3.0E+02	2E-01	1.4E+00	7.0E-04	2.4E+03	1E+00	4.8E+00	2.4E-03
Rural	2.7E+00	1E-03	1.4E+00	7.0E-04	2.0E+01	1E-02	4.8E+00	2.4E-03

[a] The most severe accidents correspond to the highest NUREG-0170 accident severity category (Category VIII) (NRC, 1977a). Results are reported for WM LLMW from PGDP, which was found to result in the highest potential accident doses. The assumptions were that 100% of the radioactive material would be released from its packaging in an accident, that 10% of the release would be entrained in an aerosol, and that 5% of the aerosolized release would be respirable.

[b] Buoyant plume rise resulting from fire for a severe accident was included in the exposure model.

[c] Neutral weather conditions result in moderate dispersion and dilution of the released plume. Neutral conditions were taken to be Pasquill Stability Class D with a wind speed of 4 m/s (9 mph). Neutral conditions occur approximately 50% of the time in the United States.

[d] Stable weather conditions result in minimal dispersion and dilution of the released plume and are thus unfavorable. Stable conditions were taken to be Pasquill Stability Class F with a wind speed of 1 m/s (2.2 mph). Stable conditions occur approximately one-third of the time in the United States.

[e] Populations extend at a uniform population density to a radius of 80 km (50 mi) from the accident site. Population exposure pathways include acute inhalation; acute cloudshine; groundshine; resuspended inhalation; resuspended cloudshine; and ingestion of food, including initially contaminated food (rural only). No decontamination or mitigative actions are taken.

[f] The MEI is assumed to be at the location of maximum exposure. The locations of maximum exposure would be 160 m (525 ft) and 400 m (1,312 ft) from the accident site under neutral and stable atmospheric conditions, respectively. Individual exposure pathways include acute inhalation, acute cloudshine, and groundshine during passage of the plume. No ingested dose is considered.

for a uniform population density within an 80-km (50-mi) radius of accidents occurring in rural, suburban, and urban population density zones. The location of the MEI after an accident is determined on the basis of atmospheric conditions and the buoyant characteristics of the released plume. The locations of maximum exposure are approximately 160 m (525 ft) and 400 m (1,312 ft) from the accident site for neutral and stable weather conditions, respectively. The dose to the MEI is independent of the location of the accident. The maximum dose to an individual (approximately 5 rem for a rail accident under unfavorable weather conditions) has a potential lifetime fatal-cancer risk of 2E-03.

E.7.4.5 Onsite Assessment Results

The onsite risks for LLMW transportation at the Hanford Site are summarized in Table E-28 for truck transportation and in Table E-29 for rail transportation. The risks presented for the transportation crew include the dose to workers in areas along the shipping route. The total dose to workers close to the route is generally much less than the dose to the actual crew members involved in transporting the waste. Risks calculated for the public include persons sharing the transportation route with waste shipments. The MEI for routine conditions, besides crew members, was considered to be a guard at a facility gate or checkpoint along the route who is exposed to each shipment for 1 minute at a distance of 5 m (16.4 ft). The total dose to the guard for all shipments is estimated to be 16 mrem. Overall, the routine onsite shipment risks are much less than the offsite shipment risks for all cases considered.

In addition, the consequences of an onsite accident at the Hanford Site are summarized in Table E-20. For the accident consequence assessment, the characteristics of LLMW from the Hanford Site were used. The MEI is located at the position where maximum impacts would occur, similar to the offsite accident consequence assessment. An exposure of 2 hours was assumed for the population of onsite workers after an accident. The impacts on the offsite population were calculated by using the population distribution in the vicinity of the Hanford Site and by assuming a 1-year exposure duration.

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E.8 Uncertainties and Conservatism in Estimated Impacts

The sequence of analyses performed to generate estimates of radiological risk for transporting radioactive waste includes (1) determining waste inventory and characteristics at each Site, (2) estimating shipment requirements, (3) determining route characteristics, (4) calculating radiation doses to exposed individuals (including estimating of environmental transport and uptake of radionuclides), and (5) estimating health effects. Uncertainties are associated with each step. Uncertainties exist in the way that the physical systems being analyzed are represented by the computational models; in the data required to apply the models (because of measurement errors, sampling errors, natural variability, or unknowns caused simply by the future nature of the actions being analyzed); and in the calculations themselves (for example, the approximation algorithms used by the computers).

In principle, one can estimate the uncertainty associated with each input or computational source and predict the resultant uncertainty in each subsequent set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final, or absolute, result. However, conducting such a full-scale quantitative uncertainty analysis is often impractical and sometimes impossible, especially for actions to be initiated at an unspecified time in the future. Instead, the risk analysis is designed to ensure—through uniform and judicious selection of scenarios, models, and input parameters—that relative comparisons of risk among the various Alternatives are meaningful. In the transportation risk assessment, this design is accomplished by uniformly applying input parameters and assumptions to all Alternatives for each waste type. Therefore, although considerable uncertainty is inherent in the absolute magnitude of the transportation risk for each Alternative, much less uncertainty is associated with the relative differences among the Alternatives in a given measure of risk.

In the following sections, areas of uncertainty are discussed for each assessment step enumerated previously, with the exception of health effects. Special emphasis is placed on identifying whether the uncertainties affect relative or absolute measures of risk. Where practical, the parameters that most significantly affect the risk assessment results are identified, and quantitative estimates of uncertainty are provided. The uncertainties involved in estimating health effects from radiological doses are discussed in Appendix D.

E.8.1 UNCERTAINTIES IN WASTE INVENTORY AND CHARACTERIZATION

The site-specific waste inventories and the physical and radiological waste characteristics are important input parameters for the transportation risk assessment. The potential amount of transportation for any Alternative is determined primarily by the projected waste inventory at each Site and assumptions about shipment configurations (packaging and shipment capacities). The physical and radiological waste characteristics are important in determining the amount of waste released during accidents and the subsequent doses to exposed individuals through multiple environmental exposure pathways.

The development of projected Site-specific inventory and waste characterization data, including identification of uncertainties, is discussed in the reports prepared for each waste type. In general, the uncertainties in the data specific to the Site and to the waste type may potentially affect the relative and absolute measures of transportation risk and are difficult to quantify. Precisely defining the impact of these uncertainties on the transportation risk analysis is difficult because of the large number of Sites and Alternatives and because of the inability to accurately quantify the uncertainty in waste characterization at each Site.

The uncertainties in the waste characterization data will be reflected to some degree in the transportation risk results. If the waste inventories are consistently overestimated (or underestimated), the resulting transportation risk estimates will also be overestimated (or underestimated) by roughly the same factor. In terms of relative risk comparisons, if the uncertainty in one Site inventory is large as compared with other Site inventories, then the uncertainties may not be comparable among different Alternatives, and meaningful relative risk comparisons are difficult. For example, if the inventory at Site A is overestimated as compared with other Sites, the risk transportation assessment results will be unduly biased toward those Alternatives that do not involve shipping Site A waste; however, the waste characterization data have been carefully developed by uniformly applying consistent methodologies and assumptions to the best available information. This approach is expected to limit the overall uncertainty in the data and the likelihood that the level of uncertainty varies significantly among Sites. For comparative purposes among Alternatives, the observed differences in transportation risks are believed to represent unbiased, reasonably accurate estimates from current information.

E.8.2 UNCERTAINTIES IN SHIPMENT CONFIGURATIONS

As stated previously, the amount of transportation required for each Alternative is partly based on assumptions about the packaging and shipment configurations for each waste type. Representative shipment configurations have been defined for each waste type on the basis of either historical or probable future shipment capacities (for example, all truck shipments of LLW are assumed to be at the regulatory weight limit). In reality, the actual shipment capacities may differ from the predicted capacities so that the projected number of shipments and, consequently, the total transportation risk would change; however, although the predicted transportation risks would increase or decrease accordingly, the relative differences in risks among consolidation Alternatives would generally remain unchanged.

E.8.3 UNCERTAINTIES IN ROUTE DETERMINATION

Representative routes have been determined between all pairs of origin and destination sites considered by the Alternatives. The routes have been determined consistent with current guidelines, regulations, and practices but may not be the actual routes that will be used in the future. In reality, the actual routes may differ from the representative ones in terms of distances and total population along the routes. Moreover, because the assessment considers wastes generated over the next 20 to 30 years, the highway and rail infrastructures and the demographics along routes may change as a function of time. Although these effects have not been accounted for in the transportation assessment, it is not anticipated that these changes would significantly affect relative comparisons of risk among Alternatives considered in the PEIS.

E.8.4 UNCERTAINTIES IN THE CALCULATION OF RADIATION DOSES

The models used to calculate radiation doses from transportation activities introduce additional uncertainty into the risk assessment process. Estimating the accuracy, or absolute uncertainty, of the risk assessment results is generally difficult. The accuracy of the calculated results is closely related to the limitations of the computational models and to the uncertainties in each of the input parameters that the model requires. The single greatest limitation facing users of RADTRAN, or any computer code of this type, is the scarcity of data for certain input parameters.

Uncertainties associated with the computational models are minimized by using state-of-the-art computer codes that have been extensively reviewed. However, because numerous uncertainties are recognized but are difficult to quantify, assumptions are made at each step of the risk assessment process that are intended to produce conservative results (that is, overestimate the calculated dose and radiological risk). Because parameters and assumptions are applied equally to all Alternatives for a waste type, this model bias is not expected to affect the meaningfulness of relative comparisons of risk; however, the results may not represent risks in an absolute sense.

To understand the most important uncertainties and conservatisms in the transportation risk assessment, the results for all cases were examined to identify the largest contributors to the collective population risk. The results of this examination are discussed briefly in the following paragraphs.

For truck shipments, the largest contributors to the collective population dose were found to be, in decreasing order of importance: (1) incident-free dose to members of the public at stops; (2) incident-free dose to transportation crew members; (3) incident-free dose to members of the public sharing the route (on-link dose); (4) incident-free dose to members of the public living along the route (off-link dose); and (5) accident dose risk to members of the public. Approximately 80 percent of the estimated public dose was incurred at stops; 15 percent was incurred by the on-link population; and 5 percent was incurred by the off-link population. In general, the accident contribution to the total risk was negligible as compared with the incident-free risk.

For rail shipments, the largest contributors to the collective population dose were found to be the following (in decreasing order of importance): (1) incident-free dose to transportation crew members; (2) incident-free dose to members of the public living along the route (off-link dose); (3) incident-free dose to members of the public at stops; (4) incident-free dose to members of the public sharing the route (on-link dose); and (5) accident dose risk to members of the public. Approximately 70 percent of the estimated public dose was incurred by the off-link population; 25 percent was incurred by the population at stops; and 5 percent was incurred by the on-link population. As with truck shipments, the accident contribution to the total risk in general was negligible as compared with the incident-free risk.

As shown previously, incident-free transportation risks are the dominant component of the total transportation risk for both truck and rail modes. The most important parameter in calculating incident-free doses is the shipment external dose rate (incident-free doses are directly proportional to the

shipment external dose rate). For calculational purposes, representative dose rates have been applied to each waste type because information is not available to predict shipment dose rates accurately on a Site-by-Site basis. The representative dose rates are based on historical shipments or waste type-specific data when possible and were selected to reflect the probable average dose rates of future shipments. In practice, the external dose rates will vary not only from Site to Site and waste type to waste type, but also from shipment to shipment at a given Site; and the rates will range above and below the levels assumed for this assessment.

Finally, the single largest contributor to the collective population doses calculated with RADTRAN was found to be the dose to members of the public at truck stops. RADTRAN uses a simple point source approximation for truck stop exposures and assumes that the total stop time for a shipment is proportional to the shipment distance. The parameters used in the stop model were based on a survey of a very limited number of radioactive material shipments that examined various shipment types in different areas of the country (Madson and Wilmot, 1982). The assumption was made that stops occur as a function of distance, with a rate of 0.011 h/km; thus, for a 1,000-km (621-mi) trip, the total would be 11 hours of stops. The further assumption was made that an average of 25 people are exposed at a distance of 20 m (66 ft) at each stop. The population dose is directly proportional to the external shipment dose rate and the number of people exposed (25) and is inversely proportional to the square of the distance ($20 \times 20 = 400$). Based on the limited data available, the parameter values used in the assessment appear to be conservative; however, data do not exist to qualitatively assess the degree of conservatism in the stop dose model. As a practical matter, DOE could conceivably take steps to control the location, frequency, and duration of truck stops, if necessary to assure that the local population does not receive excessive exposure to radiation.

E.9 Mitigative Measures

The DOE is committed to conducting all transportation-related activities in a manner protective of human health and safety. The hazards of transporting radioactive materials under both incident-free conditions and accidents are minimized by existing regulations. All activities related to transporting radioactive waste would be conducted according to applicable health-and-safety requirements of the Federal Government, States, and local jurisdictions, including requirements promulgated by DOT in 49 CFR.

Although detailed plans about waste transportation will not be prepared for major shipping campaigns until some future time, safety plans have been prepared for a program involving the transportation of TRUW to WIPP. The plans for WIPP can be considered as representative of those for future major DOE programs for waste transportation. The WIPP plans (DOE, 1990a) include provisions for the following:

- Vehicles and equipment with the best available mechanical safeguards, including personal protective equipment and speed limiters
- A facility for maintaining and inspecting equipment
- A safety program, including personnel training in safe work practices
- Stringent driver-training program and penalty provisions
- Accident and emergency training
- Constant-surveillance service for all loaded shipments
- Communications equipment and services

In reviewing the WIPP program activities, the National Academy of Sciences concluded that the "system proposed for transportation of TRUW waste to the WIPP is safer than that employed for any other hazardous material in the United States today and will reduce risk to very low levels" (DOE, 1990a).

In addition to these policies, DOE may impose administrative measures to control accumulated doses during specific circumstances. Examples of administrative controls would include requiring temporary lead shielding between loaded casks and service personnel, controlling the location and duration of service stops, and prohibiting transportation during inclement weather. These measures would ensure that all exposures are maintained below the regulatory dose limits specified in DOE Orders 5400.5 and 5480.11 (DOE, 1988c; DOE, 1990b), as well as comparable NRC limits (10 CFR 20) for members of the public and for workers.

For accidents, DOE has issued a series of orders specifying the requirements for emergency preparedness, including DOE Orders 5500.10, 5500.2B, 5500.3A, and 5500.4A (DOE, 1991a–c, 1992a). Each DOE Site has also established an emergency management program, such as the one at the Hanford Site (WHC, 1994). Procedures and agreements among DOE, other Federal agencies, and State agencies are in place to allow for effective response by all appropriate parties if a severe accident should occur.

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E.10 References

Part I

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APPENDIX E—PART II
Hazardous Waste Transportation Risk Assessment

E.11 Introduction

Part II of this appendix considers risk from hazardous waste (HW) transportation and from the hazardous waste components of low-level mixed waste (LLMW) and transuranic waste (TRUW). These wastes are regulated under the Resource Conservation and Recovery Act (RCRA). Some waste types not covered by RCRA but regulated by the States or under the Toxic Substances Control Act (TSCA: 7 United States Code [USC] 136) are also included. The transportation of each waste type for treatment and ultimate disposal is an integral component of the Alternatives being considered in the U.S. Department of Energy (DOE) Waste Management Programmatic Environmental Impact Statement (WM PEIS).

This appendix should be read in conjunction with the technical reports for HW, LLMW, and TRUW, (Lazaro et al., 1995a; Wilkins et al., 1995; Hong et al., 1995) which present inventory characterization and waste load data for each major generator within the DOE complex. These data are used for the transportation risk assessment.

Section E.12 discusses the scope of the transportation risk assessment for HW and HW components of LLMW and TRUW. Section E.13 describes packaging requirements and the distinctions between requirements for HW and those for radioactive waste. Section E.14 describes the method for selecting the most likely transportation routes for use in the risk assessment. Section E.15 describes the analytical approach used for the transportation risk assessment. Modeling input parameters and assumptions are provided in Sec' on E.16. Section E.17 presents the results of the transportation risk assessment for HW, LLMW, and TRUW. Section E.18 discusses sources of uncertainty in the assessment, focusing on areas that might affect comparisons among Alternatives. Finally, Section E.19 suggests mitigative measures that could be implemented to reduce the risk of transporting HW and HW components of LLMW and TRUW.

E.12 Scope of Assessment

This section describes the scope of the PEIS transportation risk assessment, including the treatment, storage, and disposal (TSD) Alternatives; transportation-related activities; onsite versus offsite assessments; potential vehicle- and cargo-related impacts; receptors; and transportation modes are considered. Subsequent sections provide additional details about the assessment.

E.12.1 ALTERNATIVES

HW. The HW transportation risk analysis is intended to provide input for decisions about the extent to which DOE should continue to rely on commercial facilities for treating and disposing of the nonaqueous portion of the hazardous waste stream. Four Alternatives are considered: (1) No Action, (2) Decentralized, (3) Regionalized 1 (five TSD Sites), and (4) Regionalized 2 (two TSD Sites). The specific DOE and TSD Sites associated with these Alternatives are discussed in Section E.17. The HW technical report (Lazaro et al., 1995a) contains details about TSD technologies, HW inventory and generation, existing and planned capabilities for treating and storing HW, and waste loads by Alternative.

TRUW. For TRUW, six Alternatives are considered: (1) No Action, (2) Decentralized, (3) Regionalized 1, (4) Regionalized 2, (5) Regionalized 3, and (6) Centralized. See Section E.2.2.3 for detailed descriptions of these alternatives.

LLMW. For LLMW, seven Alternatives are considered: (1) No Action, (2) Decentralized, (3) Regionalized 1, (4) Regionalized 2, (5) Regionalized 3, (6) Regionalized 4, and (7) Centralized. See Section E.2.2.4 for detailed descriptions of these alternatives.

E.12.2 DESCRIPTION OF TRANSPORTATION ACTIVITIES

As in Part I of this appendix, the radioactive waste transportation risk assessment, these HW assessments for HW and HW components of TRUW and LLMW are limited to estimating the human health risks during waste transport. The risks during waste loading, unloading, and handling before

or after shipment are not included; nor do these assessments address possible impacts from increased transportation levels on local traffic flow, noise levels, logistics, or infrastructure.

E.12.3 ONSITE VERSUS OFFSITE TRANSPORTATION

The HW transportation risk assessment includes onsite and offsite transportation. These transportation types are as defined in Section E.2.1. To estimate onsite transportation risks, site-specific values are used (when available). Models that rely on simplifying assumptions and average values for many parameters, such as road dimensions, weather conditions, and population densities, are used to estimate risk from offsite shipments. As in the radiological transportation risk assessment, the Hanford Site (Hanford) was selected as representative of conservatively estimated impacts for onsite transportation risks and is used for comparison with offsite transportation risks. On-site analyses were not conducted for TRUW and LLMW. For both of these waste types, the low risks estimated for offsite transportation indicated that risks from onsite transportation would be negligible.

E.12.4 CARGO-RELATED IMPACTS (HAZARDOUS CHEMICAL WASTES)

Cargo-related impacts to human health during HW, TRUW and LLMW transportation come from exposure resulting from container failure and chemical release during an accident (a collision with another vehicle or road obstacle). Containers used for shipping HW have been specified by the U.S. Department of Transportation (DOT) and have been assumed to preclude any significant exposure of workers or the public during routine HW transport. Type A packaging for LLMW is also designed and maintained to ensure the containers will contain and shield their contents during normal transport. TRUW is packaged in TRUPACT-II containers (i.e., external containers into which 55-gal drums are placed for transportation), decreasing further the likelihood of release under routine conditions. Accordingly, no cargo-related impacts are associated with HW transport under routine (incident-free) conditions.

The risks from HW and HW component exposure during transportation accidents can be either acute (resulting in immediate injury or fatality) or latent (resulting in cancer that becomes evident after a latency period of several years). Population risks and risks to the maximally exposed individual (MEI) have been evaluated for transportation accidents. Two acute health endpoints—potential life-threatening

effects and potential adverse effects—have been evaluated for assessing cargo-related population impacts from transportation accidents. The identification of chemicals in HW, TRUW, and LLMW with potential life-threatening effects was made by comparison with gaseous and liquid substances designated "poison inhalation hazard" (PIH) chemicals by DOT. Chemicals selected for the potential adverse effects analysis included PIHs and gaseous or liquid chemicals with inhalation toxicity values (reference concentrations) established by the U.S. Environmental Protection Agency (EPA, 1993a; EPA, 1993b).

The acute effects evaluated are assumed to exhibit a threshold, nonlinear relationship with exposure; that is, some low level of exposure can be tolerated without inducing a health effect. Chemical-specific values for the potential life-threatening concentration (PLC) and potential adverse effect concentration (PAEC) were developed to estimate risks. All individuals exposed at these levels or higher are included in HW transportation risk estimates. Use of this type of population risk descriptor, which involves estimating the number of persons exposed above a specified conservatively estimated level, is recommended under EPA guidance (EPA, 1992). Figure E-6 presents a conceptual diagram of how PLC and PAEC values were derived. Additionally, to address MEIs, locations of maximum HW concentration were identified for shipments with the largest potential releases of individual HW components.

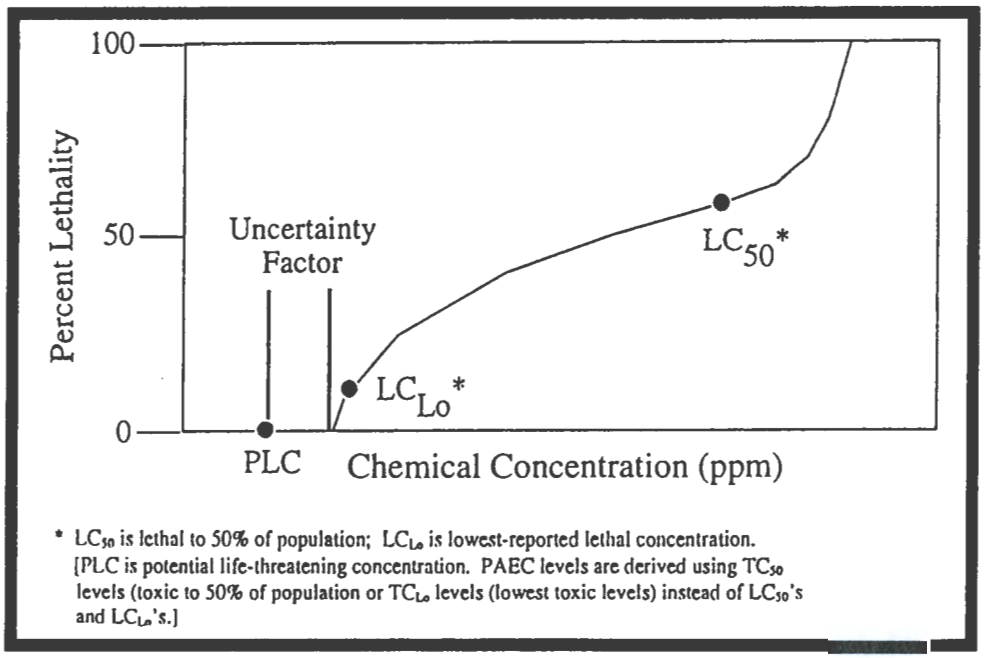

Figure E-6. Conceptualization of Threshold Health Effects.

A latent health endpoint—"increased cancer risk"—has also been used to assess the cargo-related population impacts from accidents involving carcinogen releases. Traditionally, risk assessment for chemical carcinogens characterizes risk to the MEI (EPA, 1989a). The MEI assessment is included in this HW transportation risk analysis (Section E.17.3). Additionally, for assessing risk to the general population, increased carcinogenic risk has been expressed as the number of individuals in the general population with an increased lifetime cancer risk of one in one million or greater, as recommended under EPA guidance for characterization of population risks (EPA, 1992). Cancer risks greater than one in one million have been designated as *increased cancer risk concentrations (ICRC) levels*. Overall population risk (in terms of number of excess cancers expected in the population) has not been calculated for HW as it was for radioactive waste because this calculation would require an estimate of average exposure levels in the population, while standardized cancer risk assessment methods address only MEIs. Therefore, characterizing population cancer risks associated with HW transportation as the number of individuals experiencing an increased risk of one in one million was deemed preferable. Cargo-related population cancer risks presented in this assessment cannot be directly compared with cancer risks for individuals.

Inhalation is the primary exposure route of concern for accidental release of HW, TRUW and LLMW. Direct exposure to hazardous materials by other pathways, such as ingestion or dermal absorption, is possible, but these routes are expected to result in much lower exposure than the inhalation pathway doses. The likelihood of acute effects, such as those evaluated by using PLC and PAEC values, is much lower for the ingestion and dermal pathways than for inhalation. For HW, this assessment addresses inhalation of organic vapors and gases only: the potential for the public's exposure by inhalation of particulates is considered to be much lower than that for inhalation of vapors or gases because (1) DOE transports limited quantities of solids prone to particulate formation (for example, powders), so releases would be relatively small and would result only in small particulate clouds; (2) because particulates settle rapidly, exposure of the general population located 30 meters (m) (100 feet) (ft) or farther from the release site would be minor because of low particulate concentrations; and (3) acute toxicity of inhaled particulates is low. Although some particulates are carcinogens (for example, cadmium salts), low exposure dose and duration make risks low compared with risks from vapors and gases. For LLMW, two types of exposures from solid wastes are also evaluated to maintain consistency with the radiological assessment. These are (1) volatile organic vapor emissions from contaminated spoils piles (i.e., solid waste spill on the ground); and (2) respirable aerosol fraction of organic substances from a solids spill direct to the atmosphere. Inorganic substances in LLMW were not assessed for the same

reasons given above for HW. Evaluation of releases from solids was not conducted for TRUW because the bounding risk from release of organic liquids was minimal.

E.12.5 VEHICLE-RELATED IMPACTS

For HW, vehicle-related risks (independent of a shipment's chemicals) are assessed for the same transportation routes as cargo-related impacts, for routine and accident conditions. Vehicle-related risks under routine conditions are the result of exposure to vehicle-exhaust emissions; risks are primarily associated with exposure in urban environments. Vehicle-related accident risks are fatalities and injuries resulting from direct physical trauma during an accident (not from exposure to released cargo). Fatality and injury rates specific to HW transportation are used in this assessment. For TRUW and LLMW, vehicle-related risks are presented in Part 1 of this appendix.

E.12.6 TRANSPORTATION MODE

HW. The transportation risk assessment is based on shipping HW by truck from generators to TSD facilities. Shipments by rail, barge, and aircraft, although possible, have not been considered because none of these shipment modes were identified in the baseline case data. In addition, waste volumes accumulated at a Site are generally small (onsite storage at DOE Sites is generally limited to 90 days under RCRA, unless a Part B permit is obtained); the volume to be transported is not large enough to warrant rail or barge transportation.

TRUW and LLMW. Both truck and rail transport were assessed for TRUW and LLMW. The assessments for truck and rail shipments used the same methods and accident statistics as were used for the radiological assessment.

E.12.7 RECEPTORS

In general, risks from HW, TRUW, and LLMW transportation are calculated for members of the public. Risks to the MEI are also presented. Potential risks are estimated for the collective populations of exposed people, as well as for MEIs. The collective population risk is a measure of the radiological

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risk posed to society by the Alternative being considered, and it is the primary means of comparing various Alternatives.

E.13 Waste Packaging

Regulations that govern the transportation of hazardous materials are designed to protect the public from the potential dispersal of hazardous materials. The specification of standards for packaging hazardous materials is the primary regulatory approach for ensuring the public's safety.

The packaging requirements for a specific hazardous material are determined by the level of hazard the material would present as a result of an accidental release. In the "Hazardous Materials Table" (Title 49, Part 172.01, of the *Code of Federal Regulations* [CFR]), which lists more than 4,000 chemicals in alphabetical order by proper shipping name, column 8 supplies a reference number to a part of 49 CFR 173. The part specified describes shipping requirements for a particular chemical.

Container acceptability is determined by performance-based tests (e.g., drop strength, leak resistance, hydrostatic pressure, stacking, and vibration) (49 CFR 173). A wide range of performance levels is required because of the broad spectrum of hazard levels presented by different hazardous materials.

Radioactive waste types generally have more rigorous containment requirements than HW. Most low-level waste (LLW) and LLMW can be shipped in Type A containers, typically 0.21-cubic meter (m^3) (55-gallon [gal]) drums. The DOT and U.S. Nuclear Regulatory Commission (NRC) performance specifications for Type A radioactive waste containers are comparable to the DOT requirements for HW containers. Most other radioactive wastes considered in this PEIS (HLW, Greater-Than-Class-C low-level waste [GTCC LLW], and TRUW) require Type B containers, which are subject to far more rigorous requirements than Type A containers. Examples of testing include a 9-m (30-ft) drop test (regardless of size and weight of container), a 15-m (50-ft) water immersion over an 8-hour (h) period, and a 30-minute (min) exposure to a radiation environment at or above 802 degrees Celsius (° C) (1,475 degrees Fahrenheit [° F]) and emissivity coefficient of at least 0.9.

The NRC data summarized in Section E.6.5 (Tables E–6 and E–7) and DOT-reported data on release probability during an accident (Harwood and Russell, 1990) can be used to compare the containment

performance differences between Type B containers and typical containers used for HW. The data show that the probability of a release from a Type B container resulting from an accident would be less than 9 percent and that, if a release occurs, less than 1 percent of the total shipment quantity would be released. These estimates are considered to be extremely conservative (i.e., overestimates of potential release amounts). The DOT data, based on 1985–86 data involving liquid hazardous material spills from truck accidents in the State of Missouri, show that the probability of a liquid hazardous material in bulk containment being released as the result of an accident is estimated to be 18.7 percent and that, if a release occurred, the average percentage of total cargo released would exceed 16 percent.

E.14 Routing Analysis

The HIGHWAY 3.1 computer program (described in Section E.4.2.1.1) was used for predicting the most likely truck route for each shipment of HW assessed. The HIGHWAY model provides the number of miles each route passes through various population density areas and provides estimates of population densities along each segment of routes of interest. In generating estimates of risk, the midpoint of the population density given by the HIGHWAY code for each route segment was used.

For the potential life-threatening endpoint under the No Action Alternative, transporters were contacted to determine the actual routes for each shipment. For the potential adverse effect and increased carcinogenic risk endpoints and for all four Alternatives, HIGHWAY was used to determine the most likely route by constraining the routing to maximize interstate highway use. The INTERLINE 5.0 model was used for determining rail routes for LLMW and TRUW (see Section E.4.2.1.2 for details).

E.15 Methods for Computing Transportation Risk

This section describes methods for computing risks associated with two types of transportation conditions—routine operations and accident conditions—involving the vehicle and its cargo. The routine risk estimated is solely the vehicle-related risk from inhalation of vehicle emissions; no cargo-related risk would exist because of the assumption that potential seepage would be contained. The accident risks include cargo-related risks from inhalation of a hazardous chemical (in the case of a ruptured waste container) and vehicle-related risks from the physical trauma of a traffic accident. The risk computation for routine operating conditions involves only two parameters: a risk factor for urban

vehicle exhaust exposure and the distance transported in an urban area. In addition to risks to the general population, risks to the MEI from the most hazardous chemical shipment are also assessed for accident conditions. A technical support document by Lazaro et al. (1995b) contains a more detailed discussion of this method.

The cargo-related health risk to the public (expressed as the number of individuals likely to experience an adverse health effect) from transporting a specific HW is computed for each segment of the rural, urban, or suburban population zone associated with a specific shipment route. The total risk is obtained by summing the risks for each shipment over a period of interest. This approach for determining risk from transporting HW and HW components of TRUW and LLMW is similar to the procedure for performing radiological transportation risk calculations described in Part I of this appendix. The differences in approach are principally the applied consequence assessment models and model input assumptions, and the health criteria used to compute the hazard zones (population areas at risk). These differences and the principal areas of similarity are highlighted in the following sections for the offsite and onsite risk assessment methodologies.

E.15.1 OFFSITE TRANSPORTATION

The offsite transportation risk assessment approach for routine operations and accident conditions is summarized in Figure E–7 and discussed in detail in the following sections. Section E.16.5 describes the development of health risk criteria used in this assessment.

E.15.1.1 Routine Risk Assessment Method (Vehicle-Related Risks)

The HW assessment calculates only vehicle-related routine risk, because no significant health concerns can be identified for cargo-related routine operations. The estimation of routine risks from vehicle exhausts is based on an empirical correlation linking latent inhalation mortality risk to vehicle mileage (the methods are the same as those described in Section E.5.1.1.3 of the radiological assessment).

Risks from routine transportation may be calculated by multiplying the number of kilometers traveled in urban areas by the appropriate risk factor for each HW shipment. This calculation enables the comparison of total risk of routine transport for the baseline case and the various Alternatives. Routine

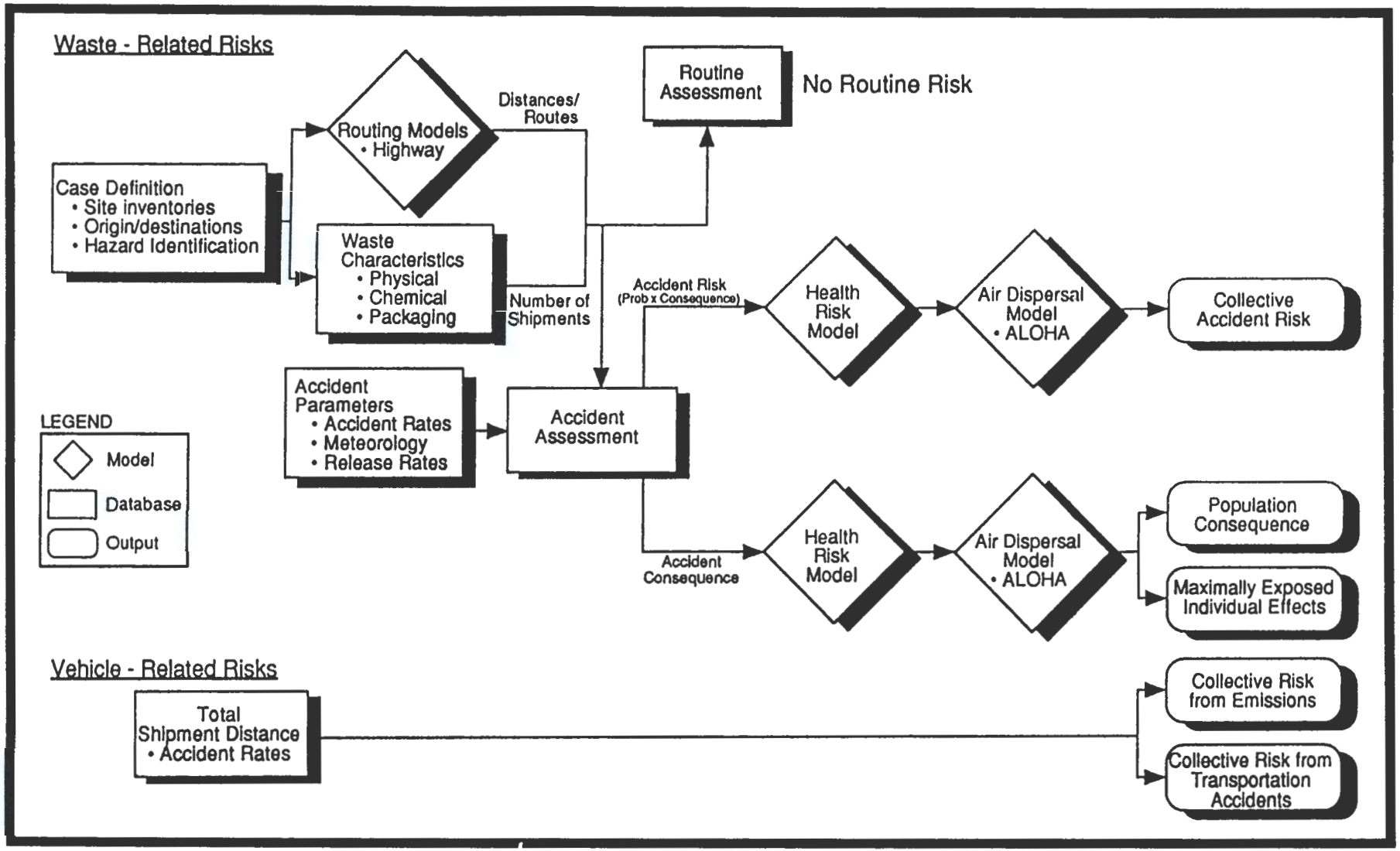

Figure E–7. Components of the Transportation Risk Assessment Method for HW and HW Components of TRUW and LLMW.

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risk for HW is presented in Section E.17, whereas routine risks for TRUW and LLMW are presented in Part 1 of this appendix.

E.15.1.2 Accident Risk Assessment Method

E.15.1.2.1 *Cargo-Related Risks*

HW. The risk assessment for HW transportation accidents considers historical hazardous material truck traffic data, including accident probabilities, cargo release likelihoods given an accident, and consequences of a range of possible transportation accidents. These accidents include low-probability accidents with high consequences and high-probability accidents with low consequences. The need to evaluate the consequences from the most severe hypothetically postulated HW transportation accident (instantaneous release of entire cargo contents), consistent with the assumptions used for the most severe radioactive accidental release, is considered. As discussed in Section E.5.1, the consequence assessment for routine and accident radioactive waste transportation conditions are computed with the RADTRAN 4 (collective populations risks) and RISKIND (individual or population subgroup risks) models (Neuhauser and Kanipe, 1993; Yuan et al., 1993). Hazardous waste transportation accident consequence assessment relies on the Areal Locations of Hazardous Atmospheres ALOHA™ model (version 5.1) (Reynolds, 1992) for the collective population and individuals. The model is a widely applied code EPA often used to help emergency field personnel implement emergency response measures.

The main differences between the ALOHA™ and the RADTRAN 4/RISKIND computer models are in the approaches for determining the source-term (chemical or radionuclide release rate or fraction), transport and dispersion, and exposure duration. The ALOHA™ model has a built-in source-term algorithm for computing the rate, quantity, and type of atmospheric release of a hazardous air pollutant, including pool evaporation from a volatile organic liquid spill. The model can handle computations for frequently encountered accidental releases from ruptured tanks, drums, and pipes. ALOHA™ incorporates a chemical data library of physical and chemical properties (such as vapor pressure, boiling point, and molecular weight) for several hundred chemical compounds. These properties, along with container content input, such as the container geometry and rupture characteristics (hole size, for

example), are used by ALOHA™ to compute chemical release rate and duration. Radionuclide release quantities for RADTRAN 4 and RISKIND are not computed by the models but are specified as release fraction input parameters. With these models, release fractions (defined as the fraction of material in a package that could be released in an accident) are assigned to each accident severity category according to the waste material's physical and chemical form. Both models assume instantaneous releases.

All three models assume that plume transport and diffusion approximate Gaussian distribution in the atmosphere. The ALOHA™ model simulates atmospheric transport and dispersion of the released substance as either a neutrally buoyant (or passive) plume or a slumping dense gas plume. In the ALOHA™ model, the selection of plume type (passive or heavy gas) from a near-surface release depends primarily on the relative density of the released toxic vapor (vapor or gas density to atmospheric density) and the ambient windspeed. Either continuous or intermittent releases and dispersion in rural or urban atmospheres can be simulated. The RADTRAN 4 and RISKIND models are limited to passive plume dispersion from instantaneous releases; these models are not designed to simulate transport and dispersion from dense gas releases commonly associated with HW chemicals. The ALOHA™ model does not account for the thermal buoyancy generated from fire plumes. Because severe accidents routinely involve fires, the RISKIND model was designed to take into account physical phenomena from the fire, such as buoyant plume rise. The risks associated with HW transportation accidents involving fire and water immersion are now being assessed with models or approaches appropriate to these conditions. These assessments will address risk associated with fire combustion products and water reaction chemistry.

Once the release and plume characteristics are computed, ALOHA™ establishes the plume hazard area or "footprint" (ground areal plume coverage with chemical concentrations greater than or equal to health criteria concentrations). Health criteria values are concentrations in air corresponding to the potential life-threatening effect, increased cancer risk, and any adverse health effect endpoints. This footprint is used to estimate the consequences of population exposure along the transportation route. No consequences are assumed within 30 m (98 ft) of the accident because homes are not likely to be located less than 30 m (100 ft) from the center of the highway. The ALOHA™-computed hazard areas, along with the chemical-specific health criteria concentration values and estimated exposure durations, are used to estimate acute and latent health effects from inhalation. In comparison, the consequences estimated by RADTRAN 4 or RISKIND, along with health risk conversion factors, are used to compute

latent cancer fatalities, cancer incidence, and serious genetic effects from inhalation and ingestion by exposed populations. The supporting technical report by Lazaro et al. (1995a) provides further description of the ALOHA™ model and modeling assumptions.

TRUW. Since only liquid or gaseous hazardous components of TRUW required evaluation, the methods used to calculate cargo-related risks were identical to those used for HW.

LLMW. The LLMW consequence assessment for HW assumes organic liquid spills and particulate releases are instantaneous as liquid and solid (as respirable fraction) aerosols. The methods used to calculate cargo-related risks for the liquid or gaseous hazardous components of LLMW were identical to those used for HW. For particulates, release fractions are estimated with the approach used for radionuclide releases (described in Section E.6.6). One additional source term is estimated for contaminated solids (containing volatile organic compounds) spilled on the ground. The emission rate is calculated with a standard evaporative gaseous emissions model (EPA, 1988). The emission rates are used in the ALOHA code to provide hazard zones ("footprints"). Details are provided in the Supplemental Information document for LLMW (Monette et al., 1995).

E.15.1.2.2 *Vehicle-Related Risks*

The risk assessment also provides an estimate of injury or fatality to truck crew members and the public as a result of physical trauma from vehicle collisions. This risk is assessed by combining data on U.S. annual deaths and injuries occurring from hazardous materials transportation accidents with total miles traveled by hazardous materials transport vehicles (DOC, 1987). The death and injury rates (unit risks) derived from these data are 9.56×10^{-9} fatalities/km (1.53×10^{-8}/mi) traveled and 6.25×10^{-8} injuries/km (1.0×10^{-7}/mi) traveled.

The risk of collision death or injury from transporting HW for each route segment is calculated as the product of the number of kilometers traveled and the unit risk factors. Risks are summed over the entire route and over all shipments for each Alternative. Vehicle-related risks for TRUW and LLMW are presented in Part I of this appendix.

E.15.2 ONSITE TRANSPORTATION

The approach used for offsite HW transportation risk calculations was also used to estimate onsite accident risks to collective populations and the MEI. The Hanford Site was selected as a large representative DOE Site for estimating the magnitude of the onsite transportation risk for hazardous and radioactive waste. The assessment requires extensive use of site-specific routing and worker population data. Sitewide characteristics such as meteorologic data and building-specific worker population densities are variable input parameters. In addition, receptor characteristics such as intake rate and location relative to the shipment route can be specified.

The three groups of receptors considered for the onsite routine risk assessment are as follows:

- Workers near the transport route (worker population dose)
- Guards at the gates of individual facilities or at checkpoints along the route
- General public near a gate (offsite collective population)

For each shipment, onsite transport HW accident consequences and the attendant health risks were calculated. The same accident and release probabilities used for the offsite risk calculations were used for the onsite risk estimates at the Hanford Site.

Based on results of the off-site analysis for TRUW and LLMW, risks from on-site transportation for these waste types would likely be very small, and were therefore not quantified.

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E.16 Input Parameters and Assumptions

E.16.1 Waste Inventory and Characterization Data

HW. The HW risk assessment modeling (HaWRAM) database was developed to support the WM PEIS transportation and technology analysis (Lazaro et al., 1994). The database was developed primarily as a tool to provide the modeling parameters identified below:

- Chemical name, its United Nations or North American identification number, and classification; that is, whether the chemical is a PLC, PAEC, or ICRC chemical
- Physical-chemical state (liquid, solid, or gas/vapor) of waste container contents
- Chemical composition and physical-chemical characteristics
- Container type (metal or fabric drum)
- Container size (0.21-m^3, 0.11-m^3, or 19-L [55-, 30-, or 5-gal] drum), number of containers in shipment, and total quantity of waste in containers shipped
- Shipment date and EPA and State manifest numbers
- Generator name, EPA identification number, and location
- TSD facility name, EPA identification number, and location

The HaWRAM database contains waste inventory and characterization data for each DOE Site, operations data for the facilities used for TSD of the wastes, and definitions of the various Alternatives. The development of the HaWRAM database is described in Hong et al. (1995) and by Lazaro et al. (1995a).

The HaWRAM database was designed to provide the following:

- Quantities of offsite HW shipments, key physical-chemical HW characteristics, and treatment technologies commercial TSD facilities used
- Data, such as chemical name, container size, chemical state, and chemical hazard designation, required to carry out a transportation risk assessment under current as well as future conditions
- Data for determining the degree and type of onsite versus offsite treatment at commercial facilities
- Data on "as-generated" or "operational" HW from industrial-type processes or laboratory research versus "remediation" HW from decommissioning or Superfund cleanup

Hazardous waste is defined under RCRA as waste either exhibiting certain standard characteristics (ignitability, corrosivity, reactivity, or toxicity) or listed under RCRA Subpart D (40 CFR 261.31). Subpart D lists approximately 800 waste categories and several hundred individual constituents as hazardous waste; however, many of these wastes are solids or nonvolatile liquids whose potential to become airborne under accident conditions is insufficient for significant exposure of the general public. Therefore, the substances evaluated for the WM PEIS transportation risk assessment were limited to those appropriate for the health endpoint being assessed, as detailed below.

For accident conditions, three health endpoints were evaluated: potential for life-threatening effects, potential for any adverse effects, and increased cancer risk. For evaluation of the potential life-threatening effects endpoint, analyses were conducted for shipments containing substances designated by DOT as PIH chemicals (criteria for PIH designation are detailed in Section E.16.5.1). Potential life-threatening concentration values were developed for estimating the risks for this endpoint. In the evaluation of potential for any adverse effects, both PIH substances and substances that may result in less severe adverse health effects on exposure were evaluated. Potential adverse effect concentration values were developed for estimating the risks for this endpoint. Increased cancer risks concentration values were developed to assess risks from substances for which sufficient evidence of carcinogenicity exists in humans or animals. Increased cancer risk concentration values were expressed as the concentrations associated with an increased lifetime cancer risk of one in one million for members of the public.

For fiscal year (FY) 1992, the HaWRAM database identifies the shipment by DOE of 48 substances to be evaluated under the potential life-threatening effects endpoint, 85 substances evaluated under the potential for any adverse effects endpoint, and 32 substances evaluated under the increased cancer risk endpoint. This constituted cargo-related risk evaluations of approximately 285 of the 1,712 shipments; however, evaluation of these shipments for the three stated health endpoints was considered to adequately represent inhalation hazards associated with collisions, because releases of less hazardous substances from other shipments are unlikely to result in a health risk to the general population. The PLC, PAEC, and ICRC values were developed for the WM PEIS risk assessment (Hartman et al., 1994). These values were derived by using toxicologic data and risk evaluation methods for emergency planning available from the EPA and other sources (EPA, 1986; EPA et al., 1987; personal communication from D.M. Maloney, ANL, to J.C. Hess, DOT Research and Special Programs Administrations, 1990; DOT, 1993b; National Research Council, 1993).

TRUW and LLMW. Reports have been prepared describing the TRUW and LLMW inventories and characteristics at each DOE site (Wilkins et al., 1995; Hong et al., 1995). These reports were used as the primary source of information for the transportation assessment. The majority of information on the hazardous-chemical compositions is derived from site-specific (process) operational knowledge. All TRUW is assumed to be radioactive material mixed with other chemical substances and divided into a number of waste-stream categories (e.g., aqueous wastes, organic liquids, contaminated soils). Concentrations of hazardous chemical constituents for each of these categories were estimated (Wilkins et al., 1995). For LLMW, classification into waste-stream categories was also conducted to facilitate the assessment (e.g., aqueous liquids, organic liquids, solid process residues; Wilkins et al., 1995).

Organic liquid and solid hazardous waste components with significant volatilization potential and inhalation toxicity values (i.e., slope factors or reference concentrations) available from the EPA were evaluated. The same health risk endpoints as for HW were considered, although for some health endpoints, zero risk was calculated (e.g., the potential for life-threatening effects endpoint for both TRUW and LLMW was zero, because no substances in the respective inventories were identified as PIH chemicals.)

E.16.2 Population Density Zones

The same three population density zones (rural, suburban, and urban) used in the radiological risk assessment (Section E.6.3) were used for the offsite population risk assessments. As for the radiological risk assessment, the onsite analysis used population densities for the Hanford Site and the town of Richland, Washington.

E.16.3 Truck Accident and Release Probabilities

A cross-classification study conducted in California (Graf and Archuleta, 1985) and cited in a Midwest Research Institute document (Harwood and Russell, 1990) provided the only data available on accident rates by highway type (rural freeway, rural nonfreeway, or urban freeway) and truck configuration (single unit, single combination, or double combination). Because HWs in the DOE complex are shipped mainly by 0.21-m^3 (55-gal) drum or smaller containers, single-unit trucks will likely be the predominant truck type used; therefore, accident rates for single-unit trucks were used in this

assessment. Also, because an accident rate for suburban freeways was required, the average of the rural and urban freeway rates was used. Rates used in the analysis (per million kilometers of truck travel) were as follows: rural freeway, 0.35; rural nonfreeway, 0.42; suburban freeway, 0.49; and urban freeway, 0.63 (0.56, 0.68, 0.79, and 1.01, respectively, per million miles). Rural nonfreeway rates were used for the small route segments from facilities to freeways.

Some States maintain more comprehensive and better monitored hazardous materials incident data than can be found in corresponding national data from DOT sources; for example, the State of Missouri's highway patrol accident reports contain data identifying whether each vehicle involved in an accident was carrying hazardous materials, what type or types of materials were carried, and whether a toxic substance was released. This format permits accurate classification of accidents by hazardous material cargo type. Missouri is one of only three States to incorporate all of these items in their reports. Because Missouri was considered the most representative (nearest the midpoint of the Nation), the data from Missouri, as cited in Harwood and Russell (1990), were used as the basis for estimating the probability of a toxic substance release after an accident. The probabilities used were 0.072 for gases in bulk and 0.187 for liquids in bulk.

In addition to these accident and release probabilities, an estimate is needed of the likely number of containers and the quantity of chemicals to spill from them as the result of a vehicle accident. An algorithm was developed to account for multiple chemicals in containers, percentage of containers in a shipment expected to be breached in an accident, and average quantity released per container. This algorithm provided the estimate of the amount spilled from the total quantity reported on HW manifest sheets (an HW tracking form mandated by Federal and, in most cases, State law for all offsite shipments of HW). The quantity of the chemical of interest per container was assumed to be equal to the total quantity in each container divided by the number of chemicals in the container (specific concentration levels were generally unavailable). This quantity was multiplied by the appropriate assumption for percent spilled and by the number of containers assumed to be breached. Data on percent spilled and number of containers breached were specific to container type (metal, plastic, glass, pressurized, or other) and size and were based on statistics from the Hazardous Materials Incident Reporting System (HMIRS) database (DOT, 1993a).

E.16.4 ATMOSPHERIC CONDITIONS

The meteorologic input to the ALOHA™ model assumes neutral stability (Pasquill Stability Class D, daytime) with moderate to overcast solar insolation, ambient temperature of 35 °C (95 °F), and a windspeed of 4 meters/second (m/s) (13.12 ft/s). Because neutral meteorologic conditions are the most frequently occurring atmospheric stability conditions in the United States, these conditions are most likely to prevail in the event of a transportation spill of a hazardous chemical or radioactive waste shipment (Part I, Section E.6.7, contains assumptions for radioactive waste exposure modeling). On the basis of observations from National Weather Service surface meteorologic stations at more than 300 locations in the United States, on an annual average, neutral conditions occur about 50 percent of the time, while stable conditions (represented by Pasquill Stability Classes E and F) occur about 33 percent of the time, and unstable conditions (represented by Pasquill Stability Classes A and B) occur about 17 percent of the time (NOAA, 1976). Regionally, neutral conditions are less prevalent in the arid Southwest and most prevalent in the Midwest and Northeast. The neutral category predominates in all seasons, but most frequently in the winter (nearly 60 percent of the observations). Neutral stability is conservative for the daytime, when most accidents occur. In its *1993 Emergency Response Guidebook* (DOT, 1993b), DOT employs neutral stability and 4.5-m/s (14.76-ft/s) windspeed for the meteorology for all transportation accidents. Although worst case conditions, such as Class F stability and windspeed of 1.5 m/s (4.92 ft/s), should be conservative for both day and night, DOT's position when developing the Initial Isolation and Protective Action Distances was to avoid multiplying conservative assumptions. This position was also adopted for modeling chemical exposure in this assessment.

E.16.5 HEALTH RISK CRITERIA

For predicting inhalation hazards associated with accidental releases, the ALOHA™ model can be applied to calculate the health consequence area by predicting the HW plume area resulting from an accident. Plume concentrations corresponding to appropriate health endpoints are required. Human health risk endpoints addressed in this assessment include the potential for life-threatening effects (evaluated using PLC values), potential for reversible or irreversible adverse effects (evaluated using PAEC values), and potential for increased cancer incidence effects (evaluated using ICRC values). The calculated risks correspond to the endpoint being assessed.

The goal of identifying PLC, PAEC, and ICRC values is to estimate the minimum concentration that could induce an adverse health effect. This minimum level is used in the ALOHA™ model to estimate the plume area with an air concentration at that level or higher. The total population exposed is assumed to be at risk for the health effect. Of the population at risk (the population within the plume), those exposed to the highest concentrations will be most likely to experience the health effect. The collective population risk calculations identify the number of individuals in the population at risk but do not differentiate the risk for individuals within the plume area. The analysis for MEI receptors addresses the highest estimated exposure levels.

E.16.5.1 Potential Life-Threatening Concentration Values

The potential for life-threatening health effects is assessed for specific HW components designated as PIHs by DOT (49 CFR 173.115, 173.132-133). These substances are assigned protective action distances in the DOT *1993 Emergency Response Guidebook* commonly used by hazardous materials incident response personnel (DOT, 1993a). Only liquids and gases are designated as PIH substances. Two criteria must be met for designation as a PIH: (1) high toxicity, based on the concentration of a chemical gas or vapor at which 50 percent of the test animals die, known as LC_{50}; and (2) for liquids, medium to high volatility. Potential life-threatening concentration values were derived for all PIH substances in the HW FY 1992 shipment inventory considered the baseline case for the No Action Alternative. These resulted in PLC values for approximately 50 chemicals. No PIH chemicals were identified in the TRUW or LLMW inventories.

Potential life-threatening concentration values are air concentrations of HW above which exposed persons are at risk for potential life-threatening health effects when exposed for the associated exposure duration. Potential life-threatening concentration values are input to the ALOHA™ code to estimate "PLC-areas at risk" (areas that equal or exceed the PLC air concentration). In deriving PLC values, three main issues must be addressed: (1) selection of toxicity values, (2) selection of appropriate uncertainty factors, and (3) exposure duration adjustment. These issues are discussed in detail in the technical support document (Lazaro et al., 1994a) and are summarized below.

E.16.5.1.1 *Toxicity Value Selection*

Toxicity data were obtained from one of two sources: (1) the Registry of Toxic Effects of Chemical Substances (RTECS) database (NIOSH, 1992), or (2) *Dangerous Properties of Industrial Materials* (Sax and Lewis, 1992). Two possible toxicity values for estimating potential human life-threatening health effects are the LC_{50}, defined above, and the human LC_{LO} defined as the lowest reported concentration of gas or vapor that has caused death in humans.

In this assessment, the lower of either (a) the lowest available human LC_{LO} value divided by an uncertainty factor of 3 or (b) the LC_{50} value for the most sensitive tested mammalian species divided by an uncertainty factor of 10 was selected as the primary toxicity value for deriving PLCs. For substances with no available LC_{50} or human LC_{LO} value, the lowest mammalian LC_{LO} value was substituted for the LC_{50} value. In the absence of either value, a short-term exposure level (STEL) for occupational exposures was multiplied by 15 to derive the PLC value, based on methods similar to those used to derive "Level of Concern" values (EPA et al., 1987). The toxicity value selection was restricted to data with associated experimental exposure times between 5 minutes and 6 hours. Experimental data with exposure times less than 5 minutes are difficult to reproduce, and data with exposure times greater than 6 hours would be inappropriate for evaluating acute health effects.

E.16.5.1.2 *Uncertainty Factor Selection*

The EPA uses uncertainty factors to allow for imprecision in deriving reference doses (RfDs) for hazardous chemical substances (EPA, 1989a). For this assessment, an uncertainty factor of 3 (approximate logarithmic mean of 1 and 10) was selected on the basis of limited EPA guidance (EPA, 1980; 1989a). To correct for variations in susceptibility among individuals in the human population, LC_{LO} values were reduced by an uncertainty factor of 3. Values for LC_{50} or mammalian LC_{LO} were reduced by an uncertainty factor of 10 (3 to correct for interspecies extrapolation and 3 to account for variations in human susceptibility—rounded from 9 to 10 for simplicity).

E.16.5.1.3 *Exposure Duration Adjustment*

The ALOHA™ code used to estimate the PLC areas at risk for transportation accidents also computes estimates of release duration. These estimates range from 1 to 60 minutes. Longer duration releases are reported as "greater than 60 minutes." The ALOHA™ model limits the puff release (forcible emission) duration to periods of 1 hour or less.

Reported LC_{LO} and LC_{50} values are associated with experimental exposure times. The estimated duration of releases computed with the ALOHA™ code are used to scale LC_{LO} or LC_{50} values in the literature from experimental exposure times to the estimated duration of exposures. Either a linear or exponential function can be assumed in scaling literature-reported toxicity values to the appropriate exposure duration. The scaling assumption resulting in the lowest PLC value was used in this assessment.

In calculating accident risks for the potential life-threatening endpoint, the assumption is that the entire population living within the PLC area at risk could experience life-threatening health effects from the exposure. This assumption is conservative because the PLC values have incorporated uncertainty factors to account for sensitive human subpopulations. Greater detail on the derivation of PLC values, the PLC values for all PIH substances contained in the HW shipping inventory, and comparisons with other available emergency planning criteria, are included in the technical support document (Lazaro et al., 1995b). Potential life-threatening concentration values and supporting information for some representative high-risk substances are presented in Table E–33.

E.16.5.2 Potential Adverse Effect Concentration Values

To estimate the occurrence probability of less severe effects, values were also developed to estimate air concentrations of HW components above which exposed persons are at risk of any adverse effect (PAEC values). Any-adverse-effect concentration values were derived for all PIH substances shipped by DOE waste generators in FY 1992 and for other substances (in either HW, LLMW, or TRUW shipment inventories) with inhalation RfDs available from the EPA (approximately 90 substances). As in the derivation of PLC values, the derivation of PAEC values requires selection of toxicity values, selection of uncertainty factors, and exposure duration adjustment, which are discussed below.

Table E-33. Values for PLC, PAEC, and ICRC for Representative Substances

Substance	Toxicity Value (ppm)	Time/Species/ Effect/Reference[a]	Inhalation RfD (mg/kg/d)[b]	Inhalation Unit Risk ($\mu g/m^3)^{-1}$ [c]	VSD[d] (mg/m^3)	Health Risk Criterion (ppm) (15 min)	Health Risk Criterion (ppm) (30 min)	Health Risk Criterion (ppm) (60 min)
PLC Values								
Arsine[e]	1.3E+02	30 min/rat	NA	NA	NA	1.9E+01	1.3E+01	6.6E+00
Chlorine	1.4E+02	1 h/mouse	NA	NA	NA	2.7E+01	1.9E+01	1.4E+01
Hydrogen fluoride[e]	5.0E+01	30 min/human/ LC_{LO}/Sax & Lewis	NA	NA	NA	2.4E+01	1.7E+01	8.3E+00
Hydrogen selenide	6.1E+00	1 h/rat/LC_{LO}	NA	NA	NA	1.2E+00	8.6E-01	6.1E-01
Nitrogen dioxide	3.0E+01	1 h/guinea pig	NA	NA	NA	6.0E+00	4.2E+00	3.0E+00
PAEC Values								
Acrolein[g]	8.7E-06	2 wk-7 yr/ human/RfC/IRIS or HEAST	5.71E-06	NA	NA	1.5E-03	7.4E-04	3.7E-04
Hydrogen chloride[g]	4.7E-03	2 wk-7 yr/ human/RfC/IRIS or HEAST	2.00E-03	NA	NA	8.0E-01	4.0E-01	2.0E-01
Hydrogen fluoride	1.2E+02	1 min/human TC_{LO}/cough, irritation	NA	NA	NA	8.2E-01	4.1E-01	2.0E-01
Hydrogen selenide	6.1E+00	1 h/rat/LC_{LO}	NA	NA	NA	1.2E-02	9.0E-03	6.0E-03
Phosgene	4.4E+02	10 min/mouse/ LC_{50}	NA	NA	NA	3.0E-01	1.5E-01	7.0E-02
1,1,1-Trichloroethane[g]	1.8E-01	2 wk-7 yr/ human/Rfc/IRIS or HEAST	NA	NA	NA	3.1E+01	1.6E+01	7.8E+00
ICRC Values[h]								
Chloroform	NA	NA	NA	2.3E-05	4.3E-05	NA	NA	5.5E+00
Dichloroethylene	NA	NA	NA	5.0E-05	2.0E-05	NA	NA	3.1E+00
Dichloromethane	NA	NA	NA	4.7E-07	2.1E-03	NA	NA	3.8e+02

Note: NA = not applicable.
[a] For PLC derivation, toxicity value is LC_{50} unless otherwise noted. For PAEC derivation, toxicity value is RfC obtained from EPA's IRIS database (EPA, 1993b) or EPA's HEAST (EPA, 1993a). Other toxicity values were obtained from the RTECS database (NIOSH, 1992), except when Sax & Lewis (Sax and Lewis, 1992) are listed.
[b] Inhalation RfD (in milligrams per kilogram per day) = [(toxicity value × molecular weight) /24.5] × ($20m^3$/d ÷ 70 kg).
[c] $(\mu g/m^3)^{-1}$ = reciprocal micrograms per cubic meter.
[d] VDS = virtually safe dose = 10^{-6} (inhalation unit risk × 1,000 μg/mg).
[e] Exponential scaling used for 15-min PAEC; linear scaling used for 60-min PAEC.
[g] Indicates that chronic RfC was adopted as subchronic RfC; value may be conservative.
[h] ICRC value = VSD × 24 h/d × 365 d/yr × 70 yr × 24.5/molecular weight (per National Research Council, 1986; National Research Council, 1993).

E.16.5.2.1 *Toxicity Value Selection*

Inhalation RfDs and reference concentrations (RfCs) developed by EPA were selected as the most applicable toxicity values for deriving PAEC values. An inhalation RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of continuous exposure to the human population (including

sensitive subgroups) that is likely to be without appreciable risk of deleterious effects (EPA, 1989b). Subchronic RfC values, applicable to exposure durations of 2 weeks to 7 years, are used when available. Otherwise, chronic RfC values are used; these values are most likely conservative, tending to overestimate risk. The RfD in milligrams per kilogram per day is derived from the RfC in milligrams per cubic meter. The EPA Integrated Risk Information System (IRIS) database and Health Effects Assessment Summary Tables (HEAST) have been used to obtain current RfC values (EPA, 1993a; EPA, 1993b).

Many PIH substances did not have available RfC values. For these substances, toxicity data, such as values for the lowest toxic concentration (TC_{LO}), were obtained from either NIOSH (1992) or Sax and Lewis (1992). Toxicity values were selected in a hierarchical fashion analogous to that used to estimate PLC values. In the absence of an RfC, the lowest human TC_{LO} value, or the lowest concentration causing any adverse effect, was selected as the most appropriate toxicity value for PAEC derivation. When human TC_{LO} values were unavailable, the following toxicity values from the literature were used (in decreasing order of preference): (1) lowest mammalian TC_{LO} values, (2) lowest human LC_{LO} values, (3) lowest LC_{50} values, (4) lowest mammalian LC_{LO} values, and (5) the STEL value. As with the PLC data, the toxicity value selection for PAEC values was restricted to data with associated experimental exposure times of between 5 minutes and 6 hours.

E.16.5.2.2 *Uncertainty Factor Selection*

For substances with available RfC values, application of uncertainty factors was unnecessary because the appropriate factors are already incorporated into the RfC value (EPA, 1993a; EPA, 1993b). Where use of other toxicity values was necessary, uncertainty factors were selected following the rationale EPA used in deriving RfC values (EPA, 1989a): (1) human TC_{LO} divided by 10 (for sensitive subpopulations); (2) mammalian TC_{LO} divided by 100 (10 for sensitive subpopulations and 10 for extrapolation from animal data to humans); (3) human LC_{LO} divided by 100 (10 for sensitive human subpopulations and 10 for extrapolation of lethality data to estimate sublethal effects); (4) LC_{50} or mammalian LC_{LO} divided by 1,000 (10 for sensitive human subpopulations, 10 for extrapolation from animal data to humans, and 10 for extrapolation of lethality data to estimate sublethal effects); and (5) the STEL value divided by 3 (for sensitive human subpopulations).

E.16.5.2.3 *Exposure Duration Adjustments*

For substances for which RfC values are available, the equation used to estimate PAEC values was based on EPA methods for estimating inhalation exposures and acceptable air concentrations of noncarcinogenic contaminants (EPA, 1989a; EPA, 1991). Details about the parameter values chosen are given in supporting documentation (Lazaro et al., 1995a).

For substances for which no RfC values are available, the exposure duration adjustment is identical to that used in generating PLC values: the exposure duration adjustment (linear or exponential) resulting in the lowest PAEC value was used in modifying toxicity values to derive PAECs.

In calculating accident risks for the endpoint presented as any adverse effect, the assumption is that the entire population living within the PAEC area at risk would experience some adverse effect from the exposure. Again, this assumption is conservative because the PAEC values have incorporated uncertainty factors to account for sensitive human subpopulations. The equation used to estimate PAECs and the computed PAEC values, along with comparisons with other available emergency planning criteria, are discussed in the technical support document (Lazaro et al., 1995b). The PAEC values and supporting information for some representative high-risk substances are presented in Table E–33.

E.16.5.3 Increased Cancer Risk Concentration Values

Hazardous chemical waste transported from DOE facilities may also be evaluated for possible increased cancer risk in exposed individuals. Values were developed to estimate the air concentrations of carcinogenic HW components above which exposed persons have an increased carcinogenic risk of one in one million or higher. These values were termed ICRC values. The risk level of one in one million was selected to represent the level below which increased risk is considered negligible.

An ICRC value was derived for each HW, TRUW, LLMW substance that met the following criteria: (1) the substance is classified as a known, probable, or possible human carcinogen (EPA, 1993a; EPA, 1993b); (2) the substance has an EPA inhalation unit-risk value; and (3) the substance is volatile enough to present significant potential for exposure of the public. Increased cancer risk concentration values

were derived for approximately 25 carcinogens. Several inorganic and organic substances were not evaluated because they are solids under ambient conditions or because the potential to volatize is minimal (for example, lindane, arsenic, beryllium, and cadmium).

The method used to generate ICRC values is that recommended by the National Research Council (1986, 1993). Because the estimation of increased cancer risk for exposure periods of less than 1 hour is highly uncertain, ICRC values were generated only for an assumed 1-hour exposure. Exposures were averaged over a 70-year lifetime. In calculating risks for individual accidents, the assumption was made that the entire population living within the ICRC area at risk would experience an increased cancer risk of one in one million or higher. The equation used to estimate ICRCs and the computed ICRC values are discussed in the technical support documents (Lazaro et al., 1995b; Monette et al., 1995; Hong et al., 1995). Table E-33 presents increased cancer risk concentration values and supporting information for some representative high-risk substances.

Population at Risk. The cargo-related population risk is calculated by estimating the minimum concentration level that could induce the adverse health effect of interest for each endpoint (potential life-threatening effects, any adverse effects, or increased cancer risk). This minimum level is used in the ALOHA™ model to estimate the plume area with an air concentration at that level or higher. The HIGHWAY 3.1 and INTERLINE 5.0 models then provides population density estimates for the plume areas in rural, suburban, or urban areas. Of the population at risk, those exposed to the highest concentrations would be most likely to experience the health effect, but the method does not differentiate the risk for individuals within the plume area. The evaluation of MEIs is intended to address the question of what maximum exposure levels could be and what health effects could be associated with those levels. To evaluate the MEI for each health endpoint, the primary factors considered were a combination of chemical potency, quantity released, and dispersion, as reflected by the exposed areas output from the ALOHA™ model (Section E.17.3 provides details). The MEI was considered to be located at the point of highest chemical concentration accessible to the public. This location was modeled to be 30 m (100 ft) from the release point (the assumed closest distance of a residence from the middle of the roadway). Although for each endpoint, many shipments of each chemical may be included in the database, only the shipment resulting in the highest chemical concentration is evaluated for the MEI.

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E.17 Risk Assessment Results

E.17.1 HAZARDOUS WASTE

E.17.1.1 Hazardous Waste Alternatives

Transportation impacts associated with the four HW Alternatives are analyzed to provide input for decisions about the extent to which DOE should continue to rely on commercial facilities for treating and disposing of the nonaqueous part of the hazardous waste stream. The analyzed HW Alternatives are (1) No Action; (2) Decentralized (optimize commercial facility selection for 11 DOE Sites, and use the limited existing and approved treatment capacity at three to five Sites); (3) Regionalized 1 (five DOE TSD Sites, including three TSD hubs or host Sites); and (4) Regionalized 2 (two DOE TSD hubs or host Sites). Hazardous waste from 11 DOE Sites representing approximately 90 percent of the HW generation in the DOE complex was analyzed. The HW inventories and the HW Alternatives for these facilities are described further in Lazaro et al. (1995a).

Hazardous waste management under the *No Action Alternative (current baseline conditions)* would continue to use existing and approved TSD facilities (for example, primarily wastewater treatment) at the DOE Sites, while most of the nonaqueous (nonwastewater) waste stream would be shipped offsite to permitted commercial facilities.

Under the *Decentralized Alternative (optimal conditions)* the no action activities would continue with an "optimized" use of DOE facilities and commercial vendors. This optimization would occur through eliminating brokering (consolidating HW with a broker from more than one generator before shipment for TSD) and by strategically selecting commercial TSD facilities by waste treatment group capability and proximity to the largest generators. These actions would limit the number of commercial facilities storing, brokering, treating, and disposing DOE HW and would select commercial TSDs as close to the principal generators as practical. Hazardous waste brokering, sometimes at several broker locations, can significantly increase the transportation miles of the original HW, depending on when and where consolidation occurs. Figure E-8 illustrates shipment routes for the Decentralized Alternative. Except for wastes to be incinerated (approximately 15 percent of the total generated organic HW) and destroyed through use as a fuel-waste (approximately 20 percent of the total organic generated HW)

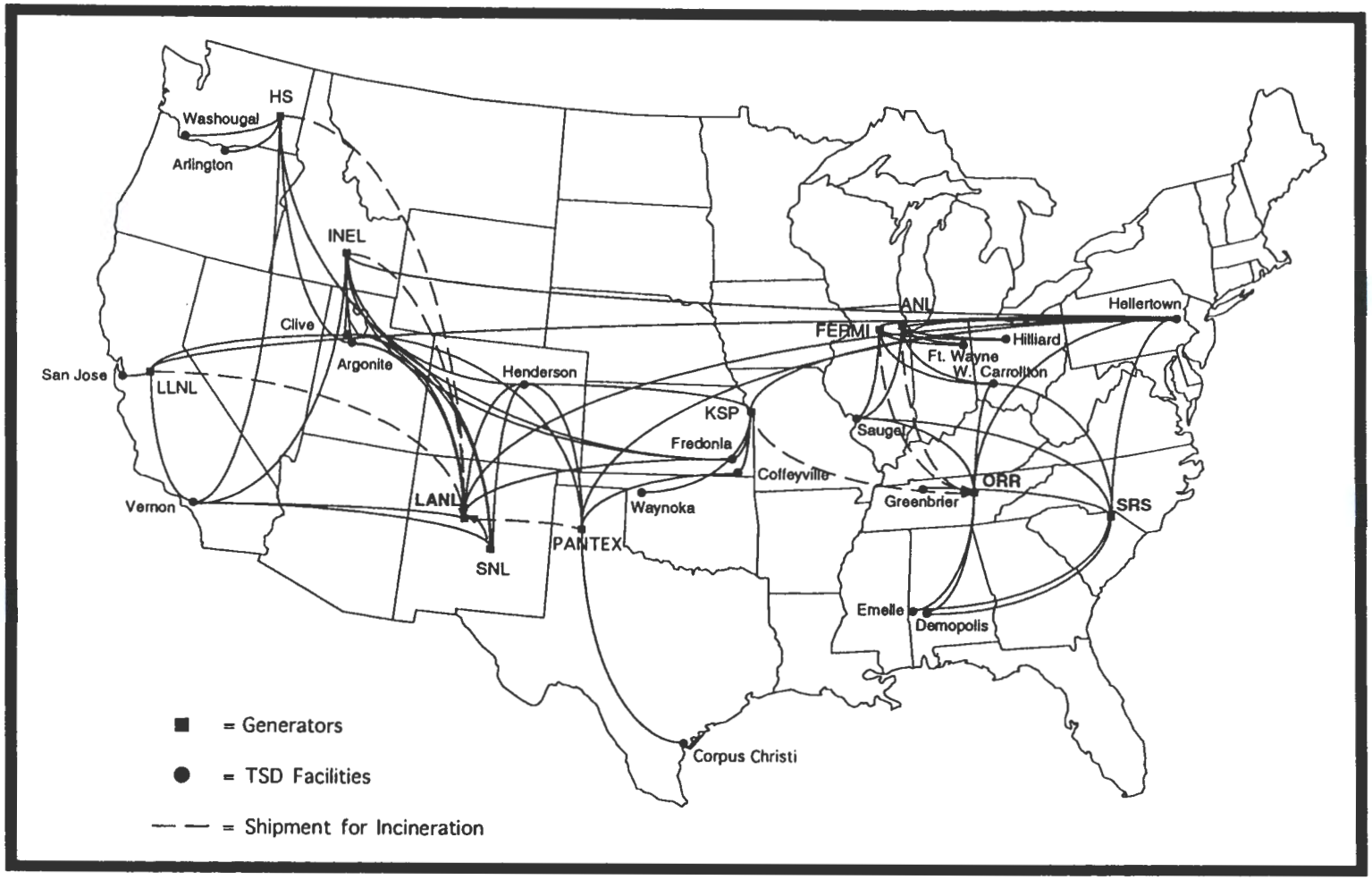

Figure E-8. Decentralization Alternative—Offsite HW Shipments From DOE Installations to Commercial TSD Facilities and to LANL and ORR for Limited Incineration.

at Los Alamos National Laboratory (LANL), Oak Ridge Reservation (ORR), and the Savannah River Site (SRS), most of the HW generated by the other eight DOE Sites included in this analysis would be sent to commercial TSD facilities.

The *Regionalized 1 Alternative* would continue no action, except that approximately 50 percent of nonaqueous HW generated by the core installations would be treated at five treatment hubs or home facilities—Hanford, Idaho National Engineering Laboratory (INEL), LANL, ORR, and SRS. Hazardous waste not treated at these Installations and the residual treated waste from these Sites would be sent to commercially licensed facilities for treatment and disposal. Under this Alternative, HW shipments would occur as follows: Pantex and Sandia National Laboratories (SNL) to the LANL hub; Lawrence Livermore National Laboratory (LLNL) to the Hanford Site hub; and the Kansas City Plant (KCP), Argonne National Laboratory-East (ANL-E), and Fermi National Accelerator Laboratory (FERMI) to the ORR hub. INEL and SRS would serve as home TSDs only for their own generated HW. The remaining smaller generators would ship to permitted commercial TSD facilities. Figure E–9 shows the transportation routes computed for the Regionalized Alternative.

The *Regionalized 2 Alternative* would continue no action, except that approximately 90 percent of the total nonwastewater HW generated by core Sites (including all organic HW) would be treated at two treatment hubs (INEL and ORR). All remaining HW would be packed and shipped to a limited number of permitted commercial TSD facilities. Under this Alternative, shipments of HW would be as follows: Hanford, LANL, Pantex, SNL, and LLNL to the INEL hub; and KCP, ANL-E, Fermi, and SRS to the ORR hub. Figure E–10 illustrates the transportation routes computed for the Regionalized 1 Alternative.

For each Alternative, vehicle-related and cargo-related risks are calculated for onsite and offsite transportation of HW. Cargo-related risks from accident conditions are computed for chemical exposure of onsite and offsite populations and for the MEI. Vehicle-related risks are quantified for death and injury from collisions and for latent cancer mortality caused by inhalation of vehicle exhausts. The collective risk for each Alternative is computed and reported below on an annual basis for the respective estimated HW shipment inventories. Shipments of HW to commercial and DOE hub TSD facilities are assumed to occur over 20 years. The average shipment period duration risk can therefore be calculated by dividing the results provided in the following tables by 20.

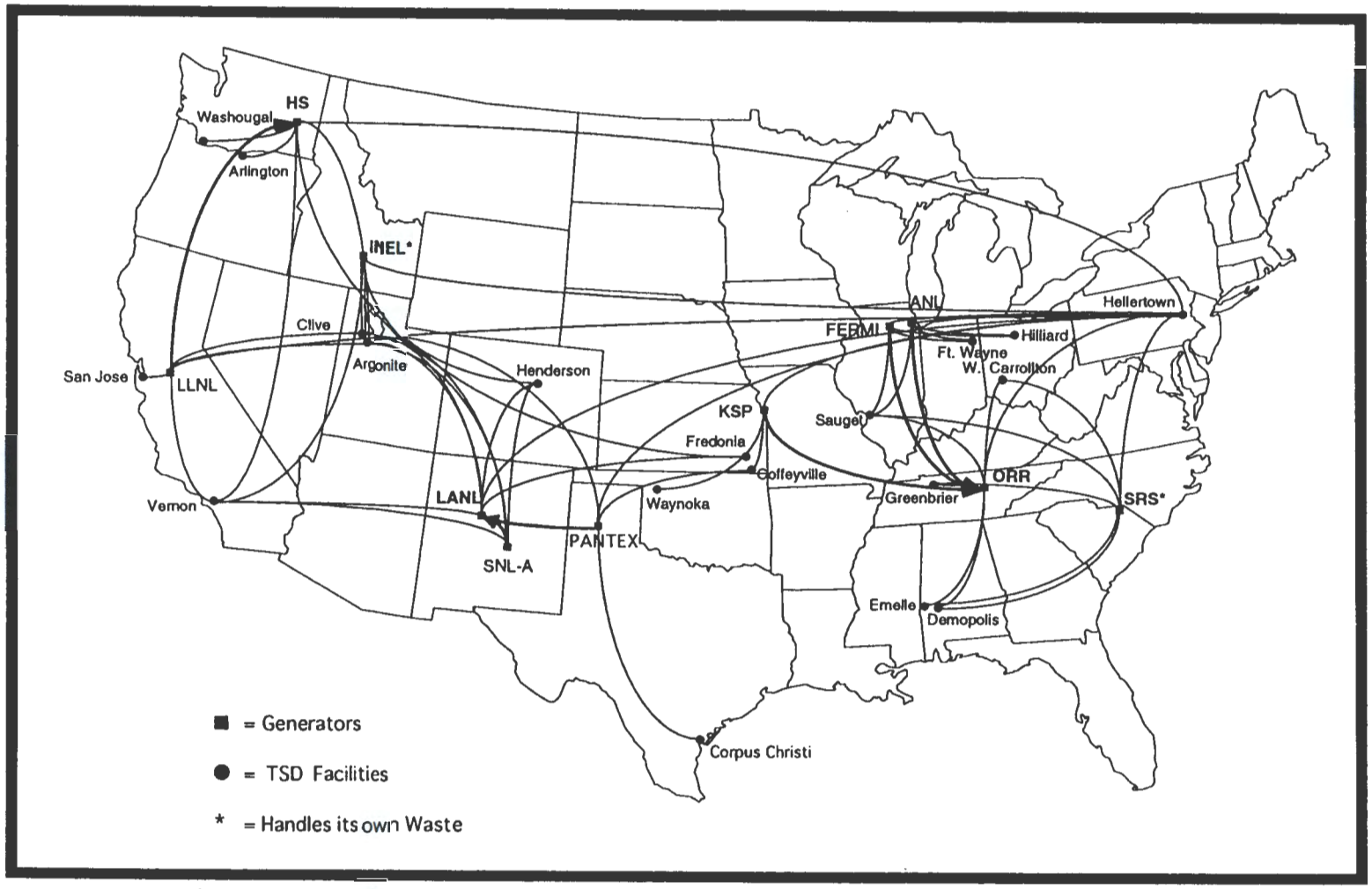

Figure E–9. Regionalized 1 Alternative—Offsite HW Shipments From DOE Installations to Three DOE Treatment Hubs (Hanford, LANL, and ORR) and to Commercial TSD Facilities.

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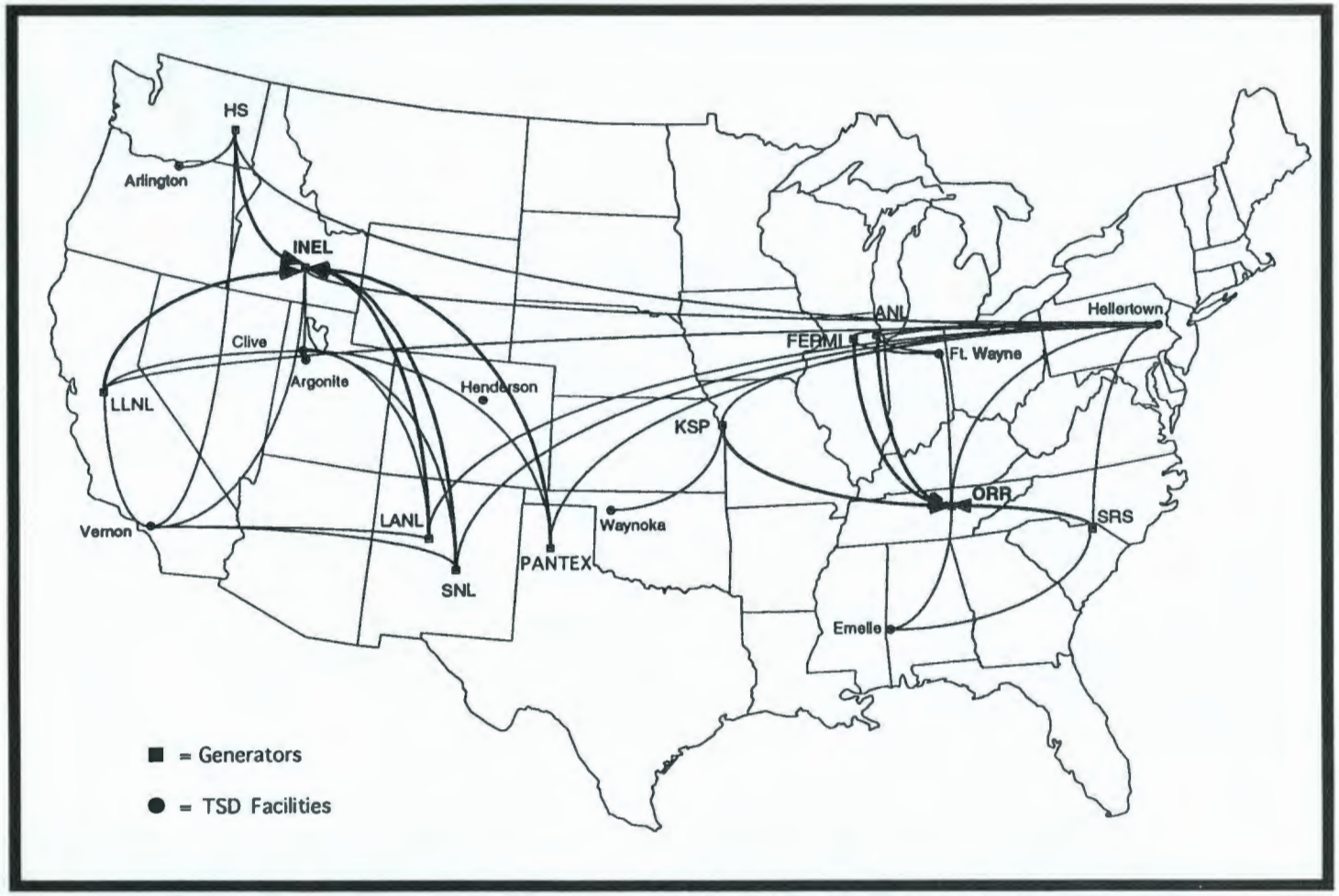

Figure E–10. Regionalized 2 Alternative—Offsite HW Shipments From DOE Installations to Two Treatment Hubs (INEL and ORR) and to Commercial TSD Facilities.

E.17.1.2 Cargo-Related Accident Transportation Risks (Chemical Dose Through Inhalation)

The assessment of transportation accident impacts associated with exposures to chemical releases are quantified in terms of risks to onsite and offsite populations for the three health endpoints described in Section E.16.5. Inhalation exposure risks from chemical releases in onsite and offsite HW transportation accidents are quantified for the four HW Alternatives. The risks are expressed as the potential number of expected adverse health effects (such as fatalities, reversible or irreversible organ or tissue damage, and individuals with an increased cancer risk of one in one million or higher) for each Alternative and as a relative risk as compared with the No Action Alternative. A detailed description of the HW shipment inventory for each Alternative is in Lazaro et al. (1995a).

The collective annual population risks to the general public and onsite workers for onsite and offsite HW transportation, under each Alternative, are presented in Table E-34. The approximate shipping routes are shown in Figures E-8 through E-10. The technical support document (Lazaro et al., 1995a) should be consulted for more detailed information (such as risks by generator, by shipment, and by chemical). Under the current system (No Action Alternative), HW is often brokered. Brokering is not assumed to occur under any but the No Action Alternative. Data on final destination of brokered HW were generally unavailable for the assessment of shipments evaluated for the potential adverse effects and cancer endpoints. Brokering data were incorporated only for shipments evaluated for the potential lethality endpoint.

E.17.1.2.1 *Potential Life-Threatening Effects*

The data in Table E-34 show the relative risk of potential life-threatening effects among Alternatives from transporting HW involving a PIH chemical spill. This table indicates that, among the Alternatives evaluated, the No Action Alternative tends to indicate a higher risk of 45 to 50 percent. Risks under the Decentralized and Regionalized Alternatives are lowest, approximately 40 percent of those under the No Action Alternative.

The risk of life-threatening effects from offsite HW shipments under the No Action Alternative is generally approximately two or more times greater than the risks for other Alternatives. The average shipment distances for containers with PIH chemicals for each Alternative are approximately 966 km

Table E-34. Population Impacts Summary for Each HW Alternative for a 20-Year Period[a]

Shipment Data and Population Risks	Alternatives			
	No Action	Decentralized	Regionalized	Regionalized 2
Shipment Summary				
Number of shipments				
PIH cargo	63	67	79	60
Carcinogenic waste	169	201	253	166
Adverse effect waste	285	344	418	283
Other waste[b]	1,712	2,026	2,483	1,685
All waste categories[c]	1,712	2,026	2,483	1,685
Distance ($km \times 10^6$)[d]				
Other waste[b]	31.54	28.68	55.69	29.98
PIH cargo	2.28	1.17	0.80	1.61
Carcinogenic waste	6.29	3.49	7.3	5.59
Adverse effect waste	13.00	8.14	16.49	11.76
All waste categories[c]	31.54	28.68	55.69	29.98
Population Risks[e] (number of individuals potentially affected)				
Cargo-related[f]				
Potential life-threatening health effects	0.146	0.058	0.056	0.076
Concerns for potential cancer incidents	2.2	1.2	2.5	2.1
Potential adverse health effects	78	48	86	60
Vehicle-related				
Physical trauma impacts[g]				
Accident fatalities	0.302	0.274	0.533	0.287
Accident injuries	1.972	1.793	3.480	1.874
Vehicle exhaust-related fatalities[h]	0.117	0.102	0.180	0.102

[a] Risks and travel distances are for the total shipment duration (20 years). To obtain the annual values, divide risks and distances by 20.
[b] Other waste is RCRA waste that did not meet the toxicity criteria for evaluation in this assessment (Section E.16.5).
[c] Total shipments and distances are less than the sum of the shipments and distances by cargo type because several waste types are generally shipped together.
[d] Distances reflect nonempty truck shipment distance multiplied by 2 to account for return of trucks with empty cargo. As a result, distance may be overestimated.
[e] Cargo-related and vehicle-related risks cannot be added because of the disparity in calculation methods and meaning of endpoints.
[f] Cargo-related risks refer to the number of people affected, computed from the product of the probability of accidental release times the number of people exposed to the health criteria concentration.
[g] Physical trauma impacts are based on total distance traveled carrying DOE HW.
[h] Vehicle exhaust impacts are based on total urban kilometers traveled by trucks carrying DOE HW in all four categories.

(600 mi) for No Action, 563 km (350 mi) for Decentralization, 418 km (260 mi) for Regionalized 1, and 708 km (440 mi) for Regionalized 2. More than 50 percent of the potential life-threatening effects risk under the No Action Alternative is contributed by about 8 percent of the HW shipments that contain PIH chemicals (5 of 63 PIH shipments). This same relationship is also true for the other three Alternatives. The reduced risk under these Alternatives is a direct result of shortening the shipment transportation distances. The specific chemicals in the five waste truckloads that contribute to most of the chemical inhalation risk are two shipments of arsine (0.03 m^3 [8 gal]), two shipments of hydrogen fluoride (0.06 m^3 [17 gal]), and one shipment of hydrogen selenide (3.8 L [1 gal]). The atmospheric transport and dispersion from the release of all five truckloads of these three chemicals was modeled as a negatively buoyant heavy or dense vapor plume. As the analysis indicates, these chemicals could present a significant but relatively small risk over the 20-year shipment duration.

E.17.1.2.2 *Any Adverse Effects*

For the any-adverse-effects endpoint, risks are highest under the No Action and Regionalized Alternatives; these risks are about 60 to 80 percent greater than risks under the Decentralized and Regionalized 2 Alternatives (Table E–33). The average transportation distances for shipments containing compounds with PAEC values are approximately 1,291 km (802 mi) for No Action, 974 km (605 mi) for the Decentralized Alternative, 1,555 km (966 mi) for Regionalized 1 and 1,236 km (768 mi) for Regionalized 2. More than 50 percent of the any-adverse-effects risk under the No Action Alternative is contributed by less than 13 percent of the shipments involving any-adverse-effect chemicals (36 of 285 shipments). This relationship also holds approximately true for the other three Alternatives. The specific chemicals in these waste shipments that contribute most of the any-adverse-effect risk are 26 shipments of hydrogen chloride (30 containers; 3.05 m^3 [807 gal]), 8 shipments of hydrogen fluoride (9 containers; 0.81 m^3 [215 gal]), 1 shipment of acrolein (1 container; 3.8 L [1 gal]), 1 shipment of hydrogen selenide (1 container; 3.8 L [1 gal]), and 1 shipment of phosgene (1 container; 3.8 L [1 gal]). Atmospheric transport and dispersion were modeled as a negatively buoyant heavy or dense vapor plume for all but the acrolein shipment. The acrolein spill was modeled as a passive neutrally buoyant vapor plume. As the analysis indicates, these chemicals are substances that could present a significant risk of adverse effects if an accidental release occurred during truck transportation.

E.17.1.2.3 *Increased Carcinogenic Risk*

The average distance of waste container shipments with carcinogenic chemicals (or compounds with an ICRC value) for each Alternative is approximately 1,609 km (1,000 mi) for No Action, 888 km (552 mi) for the Decentralized Alternative, 1,954 km (1,214 mi) for Regionalized 1, and 1,390 km (864 mi) for Regionalized 2. More than 50 percent of the carcinogenic risk under the No Action Alternative is contributed by less than 7 percent of the shipments of HW containing carcinogenic chemicals (7 of the 169 shipments). This relationship also holds approximately for the other three Alternatives. The reduced cancer risk under the Decentralized Alternative is a direct result of lessening the shipment transportation distance. The specific chemicals in the seven waste shipments that contribute to most of the total risk are five shipments of dichloroethylene (six containers; 363.4 L [96 gal]) and two tanker shipments of chloroform (27.8 m^3 [7,342 gal]). The atmospheric transport and dispersion of these chemicals were modeled as passive, neutrally buoyant vapor plumes. As the analysis indicates, these chemicals could present an increased cancer risk of one in one million or higher to the general population if an accidental release occurred during truck transportation.

E.17.1.2.4 *Discussion*

As indicated in Table E-34, with respect to potential life-threatening health effects, the No Action Alternative results in the greatest number of kilometers traveled and, thus, the highest cargo-related population risk. For the other health endpoints, the No Action Alternative does not result in the highest number of miles traveled or the highest risks; however, the mileage estimates under the No Action Alternative for the increased-cancer-risk and any-adverse-effects endpoints may be underestimated, because information on brokering was unavailable for shipments evaluated for those endpoints.

The Regionalized 2 Alternative results in higher potential life-threatening risks than the Regionalized 1 Alternative; however, with respect to the increased-cancer-risk and any-adverse-health-effects endpoints, the Regionalized 1 Alternative has greater risk. In all cases, the higher risks are associated with a greater number of kilometers traveled. The Regionalized 1 Alternative has five DOE treatment Sites and nine supporting commercial sites (five west and four east of the Mississippi River). The Regionalized 2 Alternative includes two DOE Sites and 21 commercial sites; however, the key factor here is that approximately 50 percent of the HW for the Regionalized 1 Alternative would be treated

at commercial sites and 50 percent at DOE Sites. For the Regionalized 2 Alternative, 90 percent of the waste is to go to only two Sites (the DOE locations); the remaining 10 percent of the waste is to be sent, as needed, to the commercial sites.

The explanation for why risk is greater under the Regionalized 1 Alternative than under the Regionalized 2 Alternative (for carcinogenic and any-adverse-health-effects endpoints) lies in the distance trucks travel and how full they would be with DOE waste. In the analysis, more trucks are needed to ship HW under the Regionalized 1 Alternative because the waste typically must be split between commercial and DOE treatment. A shipment was considered a DOE shipment even if the truck was only partially loaded with DOE waste; however, for the Regionalized 2 Alternative, trucks can be loaded closer to capacity, reducing the number of shipments and transportation distance because so much of the waste is going to the same place (to either of the two DOE Regionalized 2 treatment hubs). The 90-day maximum on storage at DOE Sites is the reason that full truckloads of waste are unlikely to leave DOE Sites for treatment. Once the 90-day period is over, the waste must be moved offsite for treatment. Full trucks are more the exception than the rule, considering the various treatments possible for that waste. The exception is for the PIH chemicals. Although fewer shipments are required under the Regionalized 2 Alternative for PIH chemicals, the greater distance to centralized hubs is likely the cause of higher risks.

Current practice is for a DOE Site to be one of a number of loading stops for a commercial transporter. The use of fully loaded, dedicated trucks going to a centralized location is an expensive Alternative not considered realistic. This usage is certainly not common practice for DOE at this time. In addition, the requirement that a waste container not be stored for more than 90 days also argues for the current commercial pickup procedure, which allows for a larger number of shipments spread out over the year and avoids waste accumulation. If DOE-dedicated trucks were used for the Regionalized 1 and Regionalized 2 Alternatives, the total truck distance traveled would likely be lower for the Regionalized 1 Alternative because travel distance would be less for most shipments.

E.17.1.3 Cargo-Related Accident Transportation Risks (Chemical Dose Through Inhalation) for the MEI

E.17.1.3.1 *Potential Life-Threatening Effects*

The ALOHA™-computed hazard zones for PIH chemicals are given in Table E-35. A hazard zone is the distance from the release point within which life-threatening health effects may occur. Hazard zones are presented for PIH chemicals shipped by DOE with ALOHA™-modeled releases that would result in potentially lethal plumes. Poison inhalation hazard chemicals shipped in small quantities and for which spills would not result in a potentially lethal plume are not listed.

E.17.1.3.2 *Any Adverse Effects*

Poison inhalation hazard chemicals were not included in the exposure assessment of the MEI for the potential adverse effects endpoint because the appropriate endpoint for MEI receptors is potential lethality, which was addressed under Section E.17.3.1. ALOHA™ was used to estimate the chemical

Table E-35. Hazard Zones for Potential Life-Threatening Risks to an MEI

Chemical Name	Hazard Zone[a] (m)	Number of Annual Shipments	Chemical Name	Hazard Zone[a] (m)	Number of Annual Shipments
Ammonia	93	5	Nitric acid, fuming	67	2
Arsine	719	4	Nitric oxide	137	1
Boron trifluoride	238	1	Phosgene	39	2
Bromine	39	2	Phosphine	203	2
Carbon monoxide	76	4	Sulfur dioxide	122	1
Chlorine	305	10	Titanium tetrachloride	40	1
Hydrogen fluoride	626	5	Nickel carbonyl	227	2
Hydrogen sulfide	207	8			

[a] Hazard zone indicates the distance from the release point within which life-threatening health effects may occur.

concentration and exposure duration for the MEI for the non-PIH chemicals. A standard risk equation was used (EPA, 1989b). Consistent with the chemical-specific accident risks for the public for this endpoint, parameters for a 6-year-old child were used: body weight of 21 kilograms (kg) (46.3 pounds [lb]) and moderate activity inhalation rate of 0.033 m^3/min (EPA, 1989a). These values were compared with EPA RfD values by generating a hazard quotient (HQ) (daily intake/RfD) for each chemical. An HQ greater than 1 indicates that an adverse effect for the MEI is likely. Note that the level of concern associated with exposure to these compounds does not increase linearly as HQ values exceed 1. In other words, HQ values do not represent a probability or a percentage. One may conclude that, as the HQ value above 1 increases, greater concern exists about potential adverse effects; however, assuming that an HQ value of 10 indicates that adverse health effects are 10 times more likely to occur than for an HQ value of 1 is incorrect.

Results are shown in Table E-36. Only the HQ for trichlorofluoromethane is less than 1. The other HQs range from 1.9 (for dichlorodifluoromethane) to about 29,000 (for mercury). Thus, an accidental release of any of these substances would potentially result in adverse effects for receptors at the MEI location. Because of uncertainties and conservatism associated with using EPA RfD values to evaluate single, brief exposures, the assumption may be made that the risk of adverse effects is minimal for substances with HQ values between 1 and 10. Therefore, the greatest potential for adverse effects to the MEI is associated with accidental release of the following substances: 1,1,1-trichloroethane, acrylonitrile, carbon disulfide, carbon tetrachloride, chloroform, epichlorohydrin, hexane, mercury, methylene chloride, methyl isobutyl ketone, propylene oxide, toluene, triethylamine, and vinyl acetate.

E.17.1.3.3 *Increased Carcinogenic Risk*

For the 10 carcinogens of greatest concern, risks to the MEI were calculated on the basis of potency, quantity released, and dispersivity, as reflected by exposed areas output from the ALOHA™ model. Of the carcinogens DOE shipped under the No Action Alternative, only two (benzene and vinyl chloride) are ranked in carcinogen Class A (known human carcinogens). These two chemicals were included in the MEI evaluation.

Table E-36. Any Adverse Effects Risk to an MEI

Chemical	Concentration at MEI Location (ppm)	Exposure Time (min)	Intake (mg/kg/d)	RfD (mg/kg/d)	HQ
Acetonitrile	300	25	1.4×10^{0}	1.4×10^{-1}	10
Acrylonitrile	260	20	1.3×10^{0}	5.7×10^{-4}	2,300
Acrylic acid	0.25	60	5.0×10^{-3}	8.6×10^{-4}	5.8
Aniline	0.9	60	2.3×10^{-2}	2.9×10^{-3}	7.9
Carbon disulfide	250	10	8.7×10^{-1}	2.9×10^{-3}	300
Carbon tetrachloride	140	20	2.0×10^{0}	1.7×10^{-2}	120
Chloroform	7,000	20	7.7×10^{1}	1.1×10^{-2}	7,000
Chloromethane	12,000	2	5.3×10^{0}	2.6×10^{0}	2.0
Dichlorodifluoro-methane	1,000	2	1.1×10^{0}	5.7×10^{-1}	1.9
Epichlorohydrin	8	60	2.0×10^{-1}	2.9×10^{-3}	69
Hexane	180	10	6.9×10^{-1}	5.7×10^{-2}	12
Mercury	45	60	2.5×10^{0}	8.6×10^{-5}	29,000
Methylene chloride	20,000	10	7.8×10^{1}	8.6×10^{-1}	91
Methyl ethyl ketone	1,200	25	9.9×10^{0}	2.9×10^{0}	34
Methyl isobutyl ketone	550	60	1.5×10^{1}	2.3×10^{-1}	65
Nitrobenzene	1.1	60	3.6×10^{-2}	5.7×10^{-3}	6.3
Propylene oxide	310	2	1.7×10^{-1}	8.6×10^{-3}	20
Toluene	650	55	1.5×10^{1}	1.1×10^{-1}	140
Trichlorofluoromethane	1,300	2	1.6×10^{0}	2.0×10^{0}	0.80
1,1,1-Trichloroethane	10,000	20	1.2×10^{2}	2.9×10^{-1}	410
Triethylamine	15	15	1.0×10^{-1}	2.0×10^{-3}	50
Vinyl acetate	140	20	1.1×10^{0}	5.7×10^{-2}	19

ALOHA™ was used to estimate the carcinogen concentration and duration of exposure for the MEI. A standard risk equation and standard assumptions for inhalation rate (0.014 m^3/min and body weight of 70 kg [approximately 155 lb]) were used in calculating risks (EPA, 1989b). Risks ranged from 7×10^{-6} to 2.1×10^{-4} and are presented in Table E-37. All except one are within a risk range generally considered acceptable for HW sites. The risk of 2.1×10^{-4} was for hydrazine, a chemical shipped 12 times under the No Action Alternative; therefore, increased carcinogenic risk for the MEI is insignificant for all carcinogens except hydrazine; however, note that several of these carcinogens

Table E-37. Lifetime Increased Carcinogenic Risk to an MEI

Chemical	Concentration at MEI Location (ppm)[a]	Exposure Time (min)	Intake (mg/kg/d)[b]	Slope Factor $(mg/kg/d)^{-1}$	Cancer Incidence Risk to MEI
1,2-Dibromoethane	10	60	3.6×10^{-5}	7.7×10^{1}	2.8×10^{-5}
1,3-Butadiene	450	2	1.6×10^{-5}	9.8×10^{-1}	1.5×10^{-5}
Acrylonitrile	250	20	8.5×10^{-5}	2.4×10^{-1}	2.0×10^{-6}
Benzene	600	20	3.0×10^{-4}	2.9×10^{2}	8.7×10^{-6}
Ethylene oxide	555	5	3.9×10^{-5}	$3.5 \times 10\text{-}^{1}$	1.4×10^{-5}
Formaldehyde	8,150	2	1.6×10^{-4}	4.6×10^{-2}	7.1×10^{-6}
Hydrazine	20	60	1.2×10^{-5}	1.7×10^{1}	2.1×10^{-4}
Tetrachloroethane	50	60	1.6×10^{-4}	2.0×10^{-1}	3.3×10^{-5}
Vinyl chloride	1,850	2	3.4×10^{-5}	2.9×10^{-1}	2.2×10^{-5}
Vinylidene chloride	1,250	2	7.7×10^{-5}	1.8×10^{-1}	1.4×10^{-5}

Notes: ppm = parts per million; mg/kg/d = milligram per kilogram per day.
[a] MEI is assumed to be located 30 m (100 ft) from release point.
[b] Adjusted to short-term exposures.

(specifically, acrylonitrile, ethylene oxide, and formaldehyde) are severe irritants and would be expected to result in eye and respiratory irritation to the MEI at the modeled dose levels.

E.17.1.3.4 *Accident and Routine Vehicle-Related Transportation Risks*

The risk of fatality and injury under each Alternative is directly proportional to the number of miles traveled. For this reason, risks of the Decentralized, Regionalized, and Regionalized 2 Alternatives are approximately one-half those of the No Action Alternative. These risks may be refined to reflect fatality and injury rates specific to urban, suburban, and rural roadways as these data become available. The risks of fatalities and injuries from collisions occurring during HW transport are reported in Table E-34 for each Alternative.

The routine vehicle-related risks associated with truck emissions are directly proportional to the number of miles traveled in urban areas for each Alternative: the Alternative with the most miles through urban areas has the greatest risk. The collective annual population risks (to the public and workers) from onsite and offsite HW transportation under routine nonaccident conditions are reported for each

Alternative in Table E-34. The data clearly show that routine risk estimates are linearly dependent on only one variable, total HW transportation distance. Truck shipments of HW through urban areas are 40 to 55 percent more frequent under the Regionalized 1 Alternative than under the other Alternatives.

E.17.2 TRANSURANIC WASTE

E.17.2.1 TRUW Alternatives

See Section E.2.2.3 for a detailed description of the six TRUW alternatives.

E.17.2.2 Cargo-Related Accident Transportation Risks (Chemical Dose Through Inhalation)

Organic liquids constituted the TRUW waste stream class which would present the greatest risk to the public in terms of hazardous waste impacts if a transportation accident occurred. Therefore, this case was studied in detail for both truck and rail transportation modes. For truck mode, the results revealed that the footprint area for the work-case shipment was within 30 m (98 ft) of the roadway, where no residents were assumed to live. This was true for both the "any adverse effects" and "increased carcinogenic risk health" endpoints. Recall that no substance evaluated for the potentially-life threatening endpoint was included in the TRUW inventory. Since the worst-case shipment was assessed, all other shipments would also result in zero population risks. Similarly, the plume footprint area for the worst-case rail mode shipment was also within 30 m (98 ft) of the roadway, so the population risk was zero. Therefore, the population risk for both transportation modes under all alternatives was zero, primary due to TRUW transportation in TRUPACT-II containers.

E.17.2.3 Cargo-Related Accident Transportation Risks (Chemical Dose Through Inhalation) for the MEI

Truck Mode. The impacts to the MEI are the same for all alternatives under the truck transport mode since each alternative involves transport of organic liquids via truck or rail, and the MEI for each alternative is assumed to be located 30 m (98 ft) from the roadway. The MEI calculations were

performed using assumptions and methods consistent with those presented above for hazardous waste. The carcinogenic risks and risks for any adverse effect are presented in Tables E-38 and E-39. The potential life-threatening effects endpoint was not assessed, because no PIH substances were included in the TRUW inventory. The risks to the MEI are very small but are non-zero. The risks shown are consistent with the result of zero population risks, because only carcinogenic risks of 10-6 or greater or hazard quotients of 1 or greater would result in a population risk that is reported in this assessment.

Rail Mode. The railcar accident release rates are twice the truck accident rates, because the railcars have a TRUPACT-II capacity of six (versus a truck capacity of 3). Therefore, the carcinogenic risks and risks for any adverse effects presented in Tables E-40 and E-41 are twice the risks presented for truck mode. The hazard quotient to the MEI from carbon tetrachloride is 1.06. This hazard quotient indicates a very borderline potential for any adverse effects (potential for effects is considered unlikely for hazard quotients less than 1). As a general guideline, the assumption may be made that the risk of adverse effects in minimal for substances with HQ values between 1 and 10, due to the uncertainties and conservatism associated with the use of EPA RfD values to evaluate single, brief exposures. Therefore, adverse effects due to carbon tetrachloride exposure would be unlikely unless the MEI receptor was extremely sensitive with respect to chemical exposures.

Accident and routine vehicle-related risks from transportation of TRUW are presented in Part I.

E.17.3 Low-Level Mixed Waste

E.17.3.1 LLMW Alternatives

See Section E.2.2.4 for a detailed description of the six LLMW Alternatives. In summary, the Alternatives assessed for the HW component of LLMW consist of the following:

Decentralized (49 sites treat contact-handled waste (CH); 16 sites dispose);
Regionalized 1 (11 sites treat CH; 12 sites dispose);
Regionalized 2 (7 sites treat CH; 6 sites dispose);
Regionalized 3 (7 sites treat CH; 1 site disposes);

Table E-38. Lifetime MEI Carcinogenic Risks for Mixed TRUW — Truck Mode

Chemical Name	Concentration at MEI Location (ppm)	Exposure Time (min/d)	Inhalation Air Intake (mg/kg/d)	Slope Factor $(mg/kg/d)^{-1}$	Carcino-genic MEI Risk
Carbon tetrachloride	2.15E-01	60	6.34E-07	5.25E-02	3.3E-08

Table E-39. MEI Hazard Quotients for Adverse Effect Endpoint for Mixed TRUW — Truck Mode

Chemical Name	Molecular Weight	Concentration at MEI Location (ppm)	Exposure Time (min/d)	Inhalataion Air Intake (mg/kg/d)	Inhalation RFD $(mg/kg/d)^{-1}$	Hazard Quotient Risk
1,1,1-trichloroethane	133.42	5.86E-01	60	2.1E-02	2.9E-01	7.52E-02
Carbon tetrachloride	153.82	2.15E-01	60	9.1E-03	1.7E-02	5.30E-01
Freon 113	187.38	1.85E-01	60	9.5E-03	8.6E+00	1.11E-03

Table E-40. Lifetime MEI Carcinogenic Risks for Mixed TRUW — Rail Mode

Chemical Name	Concentration at MEI Location (ppm)	Exposure Time (min/d)	Inhalation Air Intake (mg/kg/d)	Slope Factor $(mg/kg/d)^{-1}$	Carcinogenic MEI Risk
Carbon tetrachloride	4.3E-01	60	6.34E-07	5.25E-02	6.6E-08

Table E-41. MEI Hazard Quotients for Adverse Effect Endpoint for Mixed TRUW — Rail Mode

Chemical	Concentration at MEI Location (ppm)	Exposure Time (min/d)	Inhalation Air Intake (mg/kg/d)	Inhalation RFD (mg/kg/d)	Hazard Quotient
1,1,1-trichloroethane	1.17E+00	60	2.1E-02	2.9E-01	1.50E-01
Carbon tetrachloride	4.30E-01	60	9.1E-03	1.7E-02	1.06E+00
Freon 113	3.70E-01	60	9.5E-03	8.6E+00	2.22E-03

Regionalized 4 (4 sites treat CH; 6 sites dispose); and

Centralized (1 site treats and 1 site disposes of CH.

Under all alternatives, remote-handled waste would be treated and disposed of at four sites. The No Action Alternative does not involve HW transportation risks, and thus is not discussed here.

E.17.3.2 Cargo-Related Accident Transportation Risks (Chemical Dose Through Inhalation)

The collective cargo-related population risks to the general public for 10 years of off-site WM transportation are summarized in Table E–42 for truck transport mode and in Table E–43 for rail transport mode. The potential life-threatening effects endpoint was not assessed, because no PIH substances were included in the LLMW inventory. Transportation accidents involving liquid waste shipments yield much higher population risks than those involving solid waste shipments (by at least 4 orders of magnitude under the same LLMW treatment option). Due to the higher payload capacity of a railcar compared with that of a truck, the population risks are generally higher for railway than for highway transportation.

The potential population risks involving liquid waste shipments by trucks and railcars are attributed to the direct release of aerosolized liquid droplets. Truck-accident increase cancer risk and any adverse effect risk from aerosolized liquid droplets are highest for highway shipments under the Centralized Alternative, severity Category IV. Railcar-accident risks from aerosolized liquid droplets are also highest for rail shipments under the centralized alternative and the same severity category.

The potential population risks involving solid waste shipments by trucks and railcars are attributed to evaporative organic vapor emissions from a waste spoils-pile ground spill and to the direct release of respirable particulates from an overturned vehicle or a ruptured container (or both). Truck accident risks from evaporative and from respirable particulate releases are found to be zero for all of the cases. For railcar shipments, population risks are identified for respirable particulate releases under the Regionalized 2, Regionalized 3, Regionalized 4, and Centralized Alternatives. The risks for the centralized alternative are the highest, but even these risks are quite low in comparison with the transportation risk of the purely HW shipments (i.e., those with no radiological component; see Section E.17.1 above).

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Table E–42. Summary of Cargo-Related Population Risks[a] for WM (10-Year Period)[b] LLMW Shipments by Highway

Population Risks	LLMW Treatment Options					
	Decen-tralized	Region-alized 1	Region-alized 2	Region-alized 3	Region-alized 4	Centralized
Shipment summary						
Number of shipments	4.90E+02	1.81E+03	5.56E+03	1.09E+04	4.25E+03	7.52E+03
distance (km)[c]	3.75E+05	9.56E+05	4.14E+06	2.40E+07	4.34E+06	2.17E+07
Liquid wastes						
Potential for increased cancer incidence						
Severity Categories I-III	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Severity Category IV[d]	*1.68E-07*	*3.51E-07*	*0.68E-05*	*0.68E-05*	*1.08E-05*	*1.95E-04*
Severity Category V	1.29E-08	2.61E-08	4.96E-07	4.96E-07	0.80E-06	1.88E-05
Severity Category VI	0.65E-09	1.23E-09	2.28E-08	2.28E-08	3.72E-08	0.67E-06
Severity Category VII	2.03E-10	4.06E-10	0.73E-08	0.73E-08	1.14E-08	2.05E-07
Severity Category VIII	2.31E-11	4.27E-11	0.72E-09	0.72E-09	1.13E-09	2.01E-08
Potential adverse health effects						
Severity Categories I-III	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Severity Category IV[d]	*1.04E-06*	*2.82E-06*	*2.84E-05*	*2.84E-05*	*4.36E-05*	*0.90E-03*
Severity Category V	0.80E-07	2.04E-07	2.08E-06	2.08E-06	3.23E-06	0.67E-04
Severity Category VI	2.02E-09	0.99E-08	0.96E-07	0.96E-07	1.51E-07	3.13E-06
Severity Category VII	1.21E-09	3.11E-09	3.09E-08	3.09E-08	4.66E-08	0.95E-06
Severity Category VIII	1.33E-10	3.26E-10	3.05E-09	3.05E-09	4.62E-09	0.93E-07
Solid wastes (volatile-organic-contaminated soil/debris evaporative releases)						
Potential for increased cancer incidence	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Potential adverse health effects	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Solid wastes (respirable contaminated aerosol releases)						
Potential for increased cancer incidence	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Potential adverse health effects	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

[a] Cargo-related risks refer to the number of people affected and were computed from the product of the probability of accidental release times the number of people exposed to the health criteria concentration.
[b] Risks and travel distances are for the total shipping duration (10 years). To obtain the annual values, the risks and distances must be divided by 10.
[c] Vehicle-related distances are the highway distances multiplied by 2 to account for the return of empty trucks with no cargo. As a result, distances may be overestimated.
[d] Severity category presenting the highest risk.

E.17.3.3 Cargo-Related Accident Transportation Risks (Chemical Dose Through Inhalation) for the MEI

With regard to MEI risk evaluation, the increased cancer risk and any adverse effects endpoints are summarized in Tables E–44 and E–45. The methods used to estimate risks to the MEI were the same as those used for HW outlined in Sections E.17.1.3.2 and E.17.1.3.3 above. The risk calculations are

Table E-43. Summary of Cargo-Related Population Risks[a] for WM (10-Year Period)[b] LLMW Shipments by Railway

Population Risks	LLMW Treatment Options					
	Decentralized	Regionalized 1	Regionalized 2	Regionalized 3	Regionalized 4	Centralized
Shipment summary						
Number of shipments	3.60E+02	1.03E+03	2.49E+03	4.54E+03	2.05E+03	3.34E+03
distance (km)[c]	3.44E+05	7.74E+05	2.20E+06	1.09E+06	2.45E+06	1.04E+06
Liquid wastes						
Potential for increased cancer incidence						
Severity Categories I-II	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Severity Category IV[d]	4.88E-08	1.16E-07	2.12E-06	2.12E-06	2.44E-06	2.82E-05
Severity Category V	3.60E-09	0.86E-08	1.51E-07	1.51E-07	1.77E-07	2.10E-06
Severity Category VI	1.68E-10	3.84E-10	0.66E-08	0.66E-08	0.79E-08	0.99E-07
Severity Category VII	0.58E-10	1.34E-10	2.46E-09	2.46E-09	2.96E-09	3.58E-08
Severity Category VIII	0.62E-11	1.32E-11	2.44E-10	2.44E-10	3.07E-10	3.88E-09
Total	5.33E-08	1.25E-07	2.28E-06	2.28E-06	2.62E-06	2.85E-05
Potential adverse health effects						
Severity Categories I-III	0.00E+00	0.00E+00	0.00F+00	0.00E+00	0.00E+00	0.00E+00
Severity Category IV[d]	2.70E-07	0.84E-06	0.87e-05	0.87e-05	1.01E-05	1.10E-04
Severity Category V	2.00E-08	0.61E-07	0.67E-06	0.67E-05	0.73E-06	0.82E-05
Severity Category VI	0.93E-09	2.77E-09	2.79E-08	2.99E-08	3.31E-08	3.89E-07
Severity Category VII	3.22E-10	0.99E-09	1.01E-08	1.01E-08	1.22E-08	1.39E-07
Severity Category VIII	3.42E-11	0.97E-10	9.4E-06	1.01E-09	1.37E-09	1.54E-08
Total	2.91E-07	9.04E-07	9.4E-06	9.4E-06	1.09E-05	1.19E-04
Solid wastes						
(volatile-organic-contaminated aerosol releases)						
Potential for increased cancer incidence[d]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Potential adverse health effects	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Solid Wastes (respirable contaminants aersol releases)						
Severity Category I-III	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Severity Category IV[d]	0.00E+00	0.00E+00	*4.21E-11*	4.21E-11	0.52E-10	0.54E-09
Severity Category V	0.00E+00	0.00E+00	3.12E-12	3.12E-12	4.08E-12	3.98E-11
Severity Category VI	0.00E+00	0.00E+00	1.47E-13	1.47E-13	2.08E-13	1.73E-12
Severity Category VII	0.00E+00	0.00E+00	4.90E-14	4.90E-13	0.70E-13	0.65E-12
Severity Category VIII	0.00E+00	0.00E+00	0.55E-14	0.55E-14	0.85E-14	0.66E-13
Total			4.54E-11	4.54E-11	5.63E-11	5.82E-10

[a] Cargo-related risks refer to the number of people affected and were computed from the product of the probability of accidental release times the number of people exposed to the health criteria concentration.
[b] Risks and travel distances are for the total shipping duration (10 years). To obtain the annual values, the risks and distances must be divided by 10.
[c] Vehicle-related distances are the highway distances multiplied by 2 to account for the return of empty trucks with no cargo. As a result, distances may be overestimated.
[d] Severity category presenting the highest risk.

Table E-44. Lifetime Increased Cancer Risk to an MEI for LLMW Transportation

Transportation Mode	Release Mode	Chemical Name	Concentration at MEI Location (ppm)	Exposure Time (min/d)	Inhalation[a] Air Intake (mg/kg/d)	Slope Factor $(mg/kg/d)^{-1}$	Cancer Incidence Risk to MEI
Highway	Liquid aerosol (direct)	Dichloromethane	6.17E+01	60	1.01E-04	1.65E-02	1.7E-07
		Dichloroethane	2.72E+01	60	5.16E-05	9.10E-01	4.7E-06
		Tetrachloroethene	1.91E+02	60	6.08E-04	5.95E-02	3.6E-06
		Benzene	1.09E+04	60	1.63E-02	2.91E-01	4.7E-04
	Vapor spoils pile (Superfund)	Dichloromethane	1.18E-02	60	1.92E-08	1.65E-02	3.2E-11
		Dichloroethane	9.41E-02	60	1.79E-07	9.10E-01	1.6E-08
		Tetrachloroethene	1.26E-03	60	4.01E-09	5.95E-02	2.4E-11
		Benzene	1.80E-02	60	2.69E-08	2.91E-01	7.8E-10
	Particulate (severity Category II)	Dichloromethane	1.20E-02	60	1.96E-08	1.65E-02	3.2E-11
		Dichloroethane	6.97E-03	60	1.32E-08	9.10E-01	1.2E-09
		Tetrachloroethene	2.28E-02	60	7.26E-08	5.95E-02	4.3E-10
		Benzene	1.05E+01	60	1.57E-07	2.91E-01	4.6E-09
	Particulate (severity Category III)	Dichloromethane	1.20E-01	60	1.96E-07	1.65E-02	3.2E-10
		Dichloroethane	6.97E-02	60	1.32E-07	9.10E-01	1.2E-08
		Tetrachloroethene	2.28E-01	60	7.26E-07	5.95E-02	4.3E-09
		Benzene	1.05E+00	60	1.57E-06	2.91E-01	4.6E-08
	Particulate (severity Categories IV-VIII)	Dichloromethane	1.20E+00	60	1.96E-06	1.65E-02	3.2E-09
		Dichloroethane	6.97E-01	60	1.32E-06	9.10E-01	1.2E-07
		Tetrachloroethene	2.28E+00	60	7.26E-06	5.95E-02	4.3E-08
		Benzene	1.05E+01	60	1.57E-05	2.91E-01	4.6E-07
Railroad	Liquid aerosol (direct)	Dichloromethane	1.65E+02	60	2.69E-04	1.65E-02	4.4E-07
		Dichloroethane	5.85E+01	60	1.11E-04	9.10E-01	1.0E-05
		Tetrachloroethene	9.24E+02	60	2.94E-03	5.95E-02	1.7E-05
	Vapor spoils pile (Superfund)	Dichloromethane	1.96E-02	60	3.19E-08	1.65E-02	5.3E-11
		Dichloroethane	1.57E-02	60	2.98E-08	9.10E-01	2.7E-09
		Tetrachloroethene	2.53E-03	60	8.05E-09	5.95E-02	4.8E-11
		Benzene	3.31E-02	60	4.96E-08	2.91E-01	1.4E-09
	Particulate (severity Category II)	Dichloromethane	3.41E-02	60	5.56E-08	1.65E-02	9.1E-11
		Dichloroethane	1.98E-02	60	3.76E-08	9.10E-01	3.4E-09
		Tetrachloroethene	4.50E-02	60	1.43E-07	5.95E-02	8.5E-10
		Benzene	5.25E-01	60	7.86E-07	2.91E-01	2.3E-08
	Particulate (severity Category III)	Dichloromethane	3.41E-01	60	5.56E-07	1.65E-02	9.1E-10
		Dichloroethane	1.98E-01	60	3.76E-07	9.10E-01	3.4E-08
		Tetrachloroethene	4.50E-01	60	1.43E-06	5.95E-02	8.5E-09
		Benzene	5.25E+00	60	7.86E-06	2.91E-01	2.3E-07
	Particulate (severity Categories IV-VIII)	Dichloromethane	3.41E+00	60	5.56E-06	1.65E-02	9.1E-09
		Dichloroethane	1.98E+00	60	3.76E-06	9.10E-01	3.4E-07
		Tetrachloroethene	4.50E+00	60	1.43E-05	5.95E-02	8.5E-08
		Benzene	5.25E+01	60	7.86E-05	2.91E-01	2.3E-06

Note: ppm = parts per million: mg/kg/d = milligram per kilogram per day.
[a] Adjusted to short-term exposures.

Table E-45. Any Adverse Effects Risk to an MEI for LLMW Transportation

Transportation Mode	Release Mode	Chemical Name	Concentration at MEI Location (ppm)	Exposure Time (min/d)	Inhalation Air Intake (mg/kg/d)	Rfd[b] (mg/kg/d)	HQ
Highway	Liquid spill	Dichloromethane	6.17E+01	60	1.4E+00	8.6E+00	1.68E+00
		1,1,1-Trichloroethane	2.72E+01	60	10.0E-01	2.9E+00	3.49E+00
		Freon 113	1.91E+02	60	9.8E+00	8.6E+01	1.15E+00
		Toluene	1.09E+04	60	2.8E+02	1.1E+00	2.42E+03
	Spoils pile vapor (Superfund)	Dichloromethane	1.18E-02	60	2.8E-04	8.6E+00	3.22E-04
		1,1,1-Trichloroethane	9.41E-02	60	3.5E-03	2.9E+00	1.21E-02
		Freon 113	1.26E-03	60	6.5E-05	8.6E+01	7.56E-06
		Toluene	1.80E-02	60	4.6E-04	1.1E+00	3.99E-03
	Particulate (severity Category II)	Dichloromethane	1.20E-02	60	2.8E-04	8.6E+00	3.27E-04
		1,1,1-Trichloroethane	6.97E-03	60	2.6E-04	2.9E+00	8.95E-04
		Freon 113	2.28E-02	60	1.2E-03	8.6E+01	1.37E-04
		Toluene	1.05E-01	60	2.7E-03	1.1E+00	2.33E-02
	Particulate (severity Category III)	Dichloromethane	1.20E-01	60	2.8E-03	8.6E+00	3.27E-03
		1,1,1-Trichloroethane	6.97E-02	60	2.6E-03	2.9E+00	8.95E-03
		Freon 113	2.28E-01	60	1.2E-02	8.6E+01	1.37E-03
		Toluene	1.05E+00	60	2.7E-02	1.1E+00	2.33E-01
	Particulate (severity Categories IV-VIII)	Dichloromethane	1.20E+00	60	2.8E-02	8.6E+00	3.27E-02
		1,1,1-Trichloroethane	6.97E-01	60	2.6E-02	2.9E+00	8.95E-02
		Freon 113	2.28E+00	60	1.2E-01	8.6E+01	1.37E-02
		Toluene	1.05E+01	60	2.7E-01	1.1E+00	2.33E+00
Railroad	Liquid spill	Dichloromethane	1.65E+02	60	3.9E+00	8.6E+00	4.50E+00
		1,1,1-Trichloroethane	4.46E+03	60	1.6E+02	2.9E+00	5.72E+02
		Freon 113	4.94E+00	60	2.5E-01	8.6E+01	2.96E-02
		Toluene	1.21E+04	60	3.1E+02	1.1E+00	2.68E+03
	Spoils pile vapor (Superfund)	Dichloromethane	1.96E-02	60	4.6E-04	8.6E+00	5.34E-04
		1,1,1-Trichloroethane	1.78E-02	60	6.5E-04	2.9E+00	2.28E-03
		Freon 113	1.87E-04	60	9.6E-06	8.6E+01	1.12E-06
		Toluene	1.18E-02	60	3.0E-04	1.1E+00	2.62E-03
	Particulate (severity Category II)	Dichloromethane	3.41E-02	60	8.0E-04	8.6E+00	9.30E-04
		1,1,1-Trichloroethane	7.54E-02	60	2.8E-03	2.9E+00	9.68E-03
		Freon 113	5.07E-03	60	2.6E-04	8.6E+01	3.04E-05
		Toluene	2.76E-01	60	7.0E-03	1.1E+00	6.12E-02
	Particulate (severity Category III)	Dichloromethane	3.41E-01	60	8.0E-03	8.6E+00	9.30E-03
		1,1,1-Trichloroethane	7.54E-01	60	2.8E-02	2.9E+00	9.68E-02
		Freon 113	5.07E-02	60	2.6E-03	8.6E+01	3.04E-04
		Toluene	2.76E+00	60	7.0E-02	1.1E+00	6.12E-01
	Particulate (severity Categories IV-VIII)	Dichloromethane	3.41E+00	60	8.0E-02	8.6E+00	9.30E-02
		1,1,1-Trichloroethane	7.54E+00	60	2.8E-01	2.9E+00	9.68E-01
		Freon 113	5.07E-01	60	2.6E-02	8.6E+01	3.04E-03
		Toluene	2.76E+01	60	7.0E-01	1.1E+00	6.12E+00

Notes: RfD+ inhalation reference dose.

based on the maximum ambient concentrations at 30 m (98 ft) from the release point for all shipments for a single truck or railcar accident predicted by the ALOHA™ model on a chemical-specific basis. As indicated in Table E–44, carcinogenic risks for all chemicals are between 3.2×10^{-11} and 4.7×10^{-4}.

All except one are lower than or within a risk range generally considered acceptable for HW sites (i.e., 10^{-6} to 10^{-4}). The risk of 4.7×10^{-4} was for LLMW classified as soluble hydrocarbon. As a conservative assumption and to facilitate calculations, soluble hydrocarbon waste was assumed to be the carcinogenic substance benzene. The risks presented for this waste category are probably overestimated, because it is highly unlikely that the soluble hydrocarbons are actually composed of pure benzene. However, more data on the composition of the material would be required to refine the risk estimate. Adverse effects are considered possible for substances with associated hazard quotient values greater than 1. As shown in Table E–45, HQs are greater than 1 for the liquid shipment assessed (both by truck and rail), and for solid-waste truck and rail shipments of toluene under accident severity categories IV through VIII. Thus, accidental release involving any of these shipments would have a potential to result in adverse effects for receptors at the MEI location.

Increased cancer risks and any adverse effects risks are also presented in the technical support document by alternative (Monette et al., 1995).

E.18 Uncertainty

The consecution of analysis leading to estimates of transportation risk for HW and HW components of TRUW and LLMW has the following major components: (1) computation of transportation routes; (2) development of health effects criteria; (3) selection of appropriate truck accident, toxic chemical release, and ruptured container probabilities; (4) quantitative estimation of source terms and atmospheric transport and dispersion; (5) calculation of exposure areas exceeding health endpoint specific chemical concentration levels; and (6) estimation of worker, general population, and MEI risks. Various levels of uncertainty are associated with each of these components. Uncertainties exist in the way the physical systems being analyzed are represented by the computational models, in the data required to exercise the models (due to measurement errors, sampling errors, natural variability, or unknowns simply due to the future nature of the actions being analyzed), and in the calculations themselves (for example, empirical data inherent in the model structure and the theoretical assumptions

incorporated in the model). The errors in data used as input to the model or models applied to compute risk can be referred to as *parameter uncertainty*. Errors in the model algorithm or empirical data incorporated in the model can be referred to as *model uncertainty*.

In principle, one can estimate the uncertainty associated with each model input data parameter, each model empirical parameter, and each model theoretical assumption, and predict the resultant uncertainty in each set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final result (that is, human health risk); however, conducting such a full-scale quantitative uncertainty analysis is often impractical because of the lack of actual data (for example, field measurements), which does not permit development of the necessary probability distributions needed to quantify uncertainty in every parameter. This is especially true for actions to be taken in the future; however, one can typically assume that the accuracy of Gaussian model predictions of maximum ground level concentrations, such as those from ALOHA, are within a factor of 3 of corresponding field observations (Turner, 1994). The remainder of the error inherent in the risk calculations is in parameter uncertainty. Three main types of parameter uncertainty exist: random error resulting from data entry or reporting, systematic error induced from biases in data collection and analysis procedures, and errors resulting from variability over time and space (that is, meteorology or waste volumes). Certain key model input parameters can be identified for analysis that should capture the most significant contributors associated with parameter uncertainty and, when combined with model uncertainty, to the overall uncertainty in the risk assessment. These parameters come from the following six areas:

- *Meteorologic conditions* (for example, windspeed and direction, atmospheric stability, relative humidity, and ambient temperature) at the time of the accident
- *Number of shipments* of hazardous chemicals, which depends on the accuracy of the total annual shipment inventory and its variation from year to year
- *Release amounts* from any given accident caused by impact physics (the vehicle's speed, collision type, and number of vehicles involved), the location of the container rupture, and the number and contents of ruptured containers
- Hazardous material truck *accident rates* and the *release probability*, given an accident
- *Population density* in the vicinity of the accident
- *Health criteria* and extrapolation to humans, including the adjustment of each health criterion to the actual exposure time of the human to the vapor plume

Estimates of the potential range of uncertainty or variability in the absolute HW risk can be made by varying these parameters independently within probable parameter error bands or known variability bands. Although not a quantitative uncertainty analysis, this type of sensitivity analysis is useful in providing some semiquantitative estimate of potential absolute uncertainty in the risk estimates associated with each parameter. To do this, the data used to estimate the risk of potential life-threatening effects discussed in Section E.17.2.1 of this appendix were used to carry out a sensitivity analysis to estimate potential parameter error bands. Because the risk estimate results from these data show that more than 50 percent of the risk for potential life-threatening effects under the No Action Alternative is contributed by a small fraction of the total shipments (5 of 63 PIH shipments), a sensitivity analysis using these data should provide a reasonable estimate of the magnitude of parameter error bands. The specific chemicals in the five waste truckloads that contribute to most of the chemical-inhalation potential life-threatening risk are two shipments of arsine (0.03 m^3 [8 gal]), two shipments of hydrogen fluoride (0.06 m^3 [17 gal]), and one shipment of hydrogen selenide (3.8 L [1 gal]). The atmospheric transport and dispersion from the release of all five truckloads of these three chemicals were modeled as a negatively buoyant heavy or dense vapor plume.

The first parameter examined was meteorologic conditions. Although random error (error of data collection and reporting) and systematic error (error of instrument calibration) are associated with this parameter, uncertainty associated with meteorologic variability should produce variability bands that overlap the smaller error bands associated with random and systematic error. Windspeed, atmospheric stability, and ambient temperature were varied to estimate the risk associated with meteorologic variability for the top six HW shipments contributing more than 50 percent of the risk. Windspeeds were varied from 1 to 20 m/s (2.2 to 45 mi/h) for conditions of daytime neutral stability (stability Class D) with 35 °C (95 °F) and 10 °C (50 °F) ambient temperatures and were varied from 2 to 5 m/s (4.5 to 11 mi/h) for nighttime stable (stability Classes E and F) conditions with 20 °C (70 °F) and -9 °C (15 °F) ambient temperatures. The PEIS risk assessment assumed 4-m/s (9 mph) winds, neutral stability, and an ambient temperature of 35 °C (95 °F). This parameter variability produces a risk uncertainty varying from approximately a factor of 3 smaller to approximately a factor of 11 larger. Risk standard deviations range from 4.3×10^{-4} (for the arsine shipment) to 2.0×10^{-2} (for the hydrogen selenide shipment).

The uncertainty in the number of shipments per year depends on the accuracy of reported manifested waste volume inventory of PIH, ICRC, and PAEC chemicals and the year-to-year variability in

shipping these chemicals. Although risk is linear with transportation miles, the number of shipments is not linear with manifested waste volumes. With the assumption that a fully implemented waste minimization program would offset any positive bias in the waste inventory, a 20-percent reduction in volume could lead to 5 percent fewer shipment miles.

The release amount depends on many factors, such as the vehicle's speed at impact, the position and quantity of drums in the truck, and the truck type. Preliminary sensitivity analysis indicated that variations in these factors can lead up to a factor of 10 difference in risks for a single route.

Release probabilities have an approximately linear relationship to risk. The same six routes and chemicals mentioned previously were analyzed for transportation risk by using 20 percent more or less than the probabilities used in actual risk analysis. Risk results appeared to be linearly related because 20-percent higher probabilities led to an approximately 20-percent higher risk.

Changing the health criteria (for lethality) to 0.1 to 10 times the value used in the risk assessment led to dramatic changes in the risk. Typically, changes in the risk between 1 and 2 orders of magnitude resulted along any one route of the six tested. Errors of 0.1 to 10 are possible for the health criteria for different chemicals, but that range likely covers any reasonable error in estimation of that health criterion. Some cancellation of errors is likely as the risk from many routes and chemicals is summed to provide the total risk for a specific Alternative; however, the risk from the top 10 percent of the routes with the greatest risk likely dominates this summation process.

The transportation risk assessment is designed to ensure—through uniform and judicious selection of scenarios, models, and input parameters—that relative comparisons of risk among the various Alternatives are meaningful because the errors in each Alternative evaluation repeat themselves in the same way. Because the uncertainty is in the absolute risk estimates; for example, the potential number of fatalities, relying on the relative risk comparisons among Alternatives normalizes this uncertainty and therefore reduces the level of uncertainty in the comparative results. In the transportation risk assessment, input parameters and assumptions are uniformly applied to all HW Alternatives. Therefore, although considerable uncertainty is inherent in the absolute magnitude of the transportation risk for each Alternative, much less uncertainty is associated with the relative differences among the Alternatives in a given measure of risk.

E.18.1 Counterposing or Reinforcement of Errors (Absolute Uncertainty)

The previous discussion describes the major sources of parameter and model uncertainty in the HW risk analysis calculations and the ranges of likely uncertainty in those parameters and models used. For some parameters, an estimate of the possible risk value range for a 1.6-km (1-mi) segment due to the parameter range was given as well; however, the total risk calculated for a specific Alternative (and health endpoint) is actually the sum of the risk values computed for each of the many 1.6-km (1-mi) segments encompassing the many routes traveled by the many HW shipments for that Alternative (No Action, Decentralized, Regionalized 1 or 2). In this summation process for each mile, the interaction among all the previous uncertainties occurs, and errors can cancel out to some degree. One parameter that leads to a conservative estimate of risk can counterpose a second parameter value leading to an optimistic estimate of risk. Cancellation of errors occurs to some degree for only those parameters for which median-type values were chosen; for instance, if the health criteria numbers are generally conservative estimates, the effect of those parameters would generally be in the conservative direction, with error cancellation not occurring and with skewing of the total risk value to the conservative side. The interplay of uncertainties by parameter and assumption could be estimated only by using a detailed probabilistic risk assessment approach, which was not taken in this appendix. Recognizing that some error cancellation and actually some error reinforcement do occur is key to understanding the uncertainty in the final or total risk numbers computed. The effect of the combined set of parameter and model errors is estimated to be within plus or minus 1 order of magnitude for the total risk numbers presented for a specific Alternative and endpoint.

E.18.2 Relative Uncertainty

Although the absolute uncertainty may seem large from the previous discussion, the relative uncertainty is most important, and that uncertainty is believed to be sufficiently small to allow reliance on the management conclusions that result from comparing differences in the risk predictions among the Alternatives. Relative uncertainty is the uncertainty in the difference between pairs of Alternatives. Because a risk value is computed for each of the four Alternatives (and same endpoint) by using exactly the same methods, models, and parameter values, differences in the results should be caused by meaningful differences in the structure of the Alternatives; for example, with one Alternative, more miles may be covered by HW shipments than another. This relative risk is believed to be smaller than the actual differences in risk values from the various Alternatives; for example, if the risk from the

Regionalized 2 Alternative is greater than the risk from the No Action Alternative, the behavior—of Regionalized 2 being larger than No Action—is believed to be accurate, although the actual risk numbers computed may each contain significant error. The accuracy of these statements about relative risk are critical to the meaning of the risk analyses in this PEIS.

E.19 Mitigative Measures

When transporting HW and LLMW, DOE follows all applicable regulations of DOT and EPA, such as using absorbent overpacking to prevent liquid releases, using placards, preparing manifests, and employing licensed transporters. For each named chemical, the CFR identifies permissible containers for transporting that chemical. The containers are ranked based on their sturdiness and the hazard class of the chemical to be transported. These regulations are designed to minimize the risks of transporting HW and to allow for rapid mitigative action in the event of an accidental release.

The DOE may consider additional measures to further minimize risks associated with HW and LLMW transportation. Examples include rerouting shipments through low-population density areas, pretreating the more dangerous chemicals at DOE Sites, or substituting for the chemicals that lead to the greatest risk. Where possible, the potential decrease in risk that could be achieved through using rail transport may also be investigated.

E.20 References

Part II

49 CFR 172.101.

49 CFR 173.

40 CFR 261.31.

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49 CFR 173.132.

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Appendix F

Treatment and Storage Facility Accidents

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Acronyms and Abbreviations

The following is a list of the acronyms and abbreviations (including units of measure) used in this appendix. Some acronyms used only in tables are defined in those tables.

Acronyms

ARF	airborne release fraction
BTX	benzene, toluene, and xylene
CCl_4	carbon tetrachloride
Cd	cadmium
CFR	Code of Federal Regulations
CH	contact-handled
CIF	Consolidated Incineration Facility
CO	carbon monoxide
CO_2	carbon dioxide
CPC	Chemical Process Cell
Cr	chromium
CSB	Consolidated Storage Building
CST	chemical source term
DF	damage fraction
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DST	double-shell tank
DWPF	Defense Waste Processing Facility
EIS	environmental impact statement
EM	Environmental Management
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ER	environmental restoration
FEMP	Fernald Environmental Management Project
FY	fiscal year
GDC	general design criterion
GTCC	Greater-Than-Class-C
GWSB	Glass Waste Storage Building
^3H	tritium
Hanford	Hanford Site
HCl	hydrogen chloride
HEPA	high-efficiency particulate air
Hg	mercury
HLW	high-level waste
H_2O	water
HW	hazardous waste
HWSF	hazardous waste storage facility
HWVP	Hanford Waste Vitrification Plant
IFSF	Interim Fuel Storage Facility

INEL	Idaho National Engineering Laboratory
K-25	K-25 Site
LANL	Los Alamos National Laboratory
LDR	land disposal restriction
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
LPF	leak path factor
MAR	material at risk
MEI	maximally exposed individual
NEPA	National Environmental Policy Act
NH_3	ammonia
NO_x	nitrogen oxides
NPH	natural phenomena hazards
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PC	performance category
PEIS	Programmatic Environmental Impact Statement
PIH	poison inhalation hazard
PREPP	Process Experimental Pilot Plant
RARF	respirable airborne release fraction
RCRA	Resource Conservation and Recovery Act
RF	respirable fraction
RFETS	Rocky Flats Environmental Technology Site
RH	remote-handled
RWMC	Radioactive Waste Management Complex
SAR	safety analysis report
SCT	shielded canister transport
SO_2	sulfur dioxide
SQUG	Seismic Qualification Users Group
SRS	Savannah River Site
STRF	source term release fraction
SWEPP	Solid Waste Experimental Pilot Plant
TC	treatment code
TRUW	transuranic waste
TSD	treatment, storage, and disposal
WAC	waste acceptance criteria
WCSF	Waste Canister Storage Facility
WERF	Waste Experimental Reduction Facility
WIPP	Waste Isolation Pilot Plant
WM	waste management
WRAP	Waste Receiving and Processing Facility
WVDP	West Valley Demonstration Project

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Abbreviations

atm	atmosphere(s)
°C	degree(s) Celsius
Ci	curie(s)
cm	centimeter(s)
cm^3	cubic centimeter(s)
d	day(s)
°F	degree(s) Fahrenheit
ft	foot (feet)
ft^2	square foot (feet)
ft^3	cubic foot (feet)
g	gram(s)
g	gravity (acceleration due to)
gal	gallon(s)
h	hour(s)
kg	kilogram(s)
km	kilometer(s)
kPa	kilopascal(s)
L	liter(s)
lb	pound(s)
m	meter(s)
m^3	cubic meter(s)
mi	mile(s)
min	minute(s)
mm	millimeter(s)
mol	mole(s)
MPa	megapascal(s)
psig	pound(s) per square inch gauge
s	second(s)
yd^3	cubic yard(s)
yr	year(s)
μm	micrometer(s)

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APPENDIX F
Treatment and Storage Facility Accidents

F.1 Introduction and Overview

F.1.1 SUMMARY

This appendix documents the methodology and computational framework for facility accident analyses performed for the U.S. Department of Energy (DOE) Waste Management Programmatic Environmental Impact Statement (WM PEIS). The methodology is in compliance with the most recent DOE guidance EIS (DOE, 1993a) in that it considers the spectrum of accident sequences that could occur in activities covered by the WM PEIS and uses a graded approach emphasizing the risk-dominant scenarios to facilitate discrimination among the various WM PEIS alternatives. Although it allows reasonable estimates of the risk impacts associated with each alternative, the main goal of the accident analysis methodology is to allow reliable estimates of the relative risks among the alternatives. Rather than developing all accident sequences in detail the accident models are systematically applied to approximate the key source term parameters as functions of (1) the phenomenology and severity of the accident, (2) the process parameters, (3) the characteristics of the facility, and (4) the properties of the waste types. This allows many of the uncertainties in the data that are reflected in estimates of absolute risk to be canceled in estimates of relative risk providing a sufficient and scrutable basis for discriminating among alternatives.

The output of the facility accident analyses is a specification for each waste type of the accidents potentially important to human health risk, an assessment of the frequencies of these accidents, and an evaluation of the radiological and chemical source terms resulting from these accidents. A radiological source term is defined by specifying the amount (in curies) of each radionuclide released during an accident, where release is conservatively assumed to be instantaneous. A chemical source term is defined by specifying the rate and duration of release for each toxic chemical released during an accident. The frequencies of the accidents and the results of the source term evaluation are provided as input to the WM PEIS for calculations of the human health and risk impacts.

The accident sequences analyzed were selected for their potential importance to human health. In light of the lack of specific process and facility design information, (including intrasite locations and associated characteristics of these locations, the analyses focused on accidents with potential airborne releases to the atmosphere. Although disposal alternatives are included in the WM PEIS waste management options, the details of ultimate disposal are not addressed. Consequently, accidents were not developed for this phase of waste management.

Numerous DOE waste management sites were analyzed in this study. However, generic DOE facility characteristics were assumed in developing the accident sequences for all sites. Facility waste inventories assumed for each DOE site were derived from the storage inventories, generation rates, and treatment throughputs developed in the WM PEIS. Site safety documentation was used to help identify the frequencies and potential risk importance of accident initiators affected by site characteristics such as seismic or tornadic vulnerability or proximity to airports. However, existing facility documentation and accident data were used only for general guidance in source term development; thus, the accident analyses herein may not necessarily duplicate the results produced in individual site environmental impact statements (EISs) or safety documents where specific facilities are assessed.

F.1.2 Scope and Objectives

The requirements on the scope of the accident analysis are driven by the scope of the WM PEIS and by DOE guidance discussed subsequently. The WM PEIS addresses strategic alternatives for management of five different types of waste in the DOE complex: low-level waste (LLW), hazardous waste (HW), high-level waste (HLW), low-level mixed waste (LLMW), and transuranic waste (TRUW). For each waste type, four categorical strategies have been devised for the consolidation of wastes for treatment, storage and disposal (TSD): (1) no action, where existing sites will generally store and treat their own wastes consistent with currently approved plans; (2) centralization, where from one to a few DOE sites will be used to treat, store, and dispose of a given waste type from the entire DOE complex; (3) regionalization, where several sites distributed throughout the country will be used to treat, store, and dispose of that waste type for their geographic regions; and (4) decentralization, where regionalization is extended to include more sites. Alternatives for consolidation of waste involve both existing and conceptual-design facilities at DOE sites throughout the country. Moreover, a number of technologies for waste treatment and options for storage are to be assessed for each type of waste.

The most recent guidance (DOE, 1993a) from the Office of National Environmental Policy Act (NEPA) Oversight within the DOE calls for consideration of the spectrum of accident scenarios that could occur in activities encompassed by the actions evaluated in the WM PEIS. This guidance also calls for a graded approach emphasizing the risk-dominant scenarios. Determination of risk dominance requires assessment of both the likelihood and the severity of plausible accident scenarios that could present a significant health hazard to either the workforce or the public. The spectrum of accident scenarios includes all accidents important to risk, from low-frequency events with potentially high consequences (as typified by accident sequences associated with natural phenomena such as earthquakes) to relatively high-frequency events with very low consequences (as typified by routine industrial accidents).

The broad scope of the WM PEIS and the recent NEPA guidance result in a very large number of combinations of possible TSD options, existing or new facilities, and related possible accident scenarios to be evaluated for assessing management alternatives for each waste type. Accordingly, one obvious objective of the methodology for accident analysis was the development of a strategy that would enable focus on the risk-dominant sites and facilities for the storage and treatment operations and on the alternatives for waste consolidation under consideration in the WM PEIS for each waste type.

A second objective was to develop a methodology for accident analysis that would allow sufficient discrimination of risk impacts among the various options and alternatives to support the WM PEIS decision-making process. Although the method must provide reasonable estimates of the risk impacts associated with each alternative, providing reliable estimates of the relative risks among the alternatives is more important. To accomplish these goals, the accident models must be adequate to approximate the key source term parameters as a function of the phenomenology and severity of the accident, the process parameters, the characteristics of the facility, and the properties of the waste types. Although developing all accidents in detail is not necessary, systematically applying the underlying approximate models is necessary. Many of the uncertainties in the data that are reflected in estimates of absolute risk tend to be canceled in estimates of relative risk. Thus, systematic application of the models is required to provide a sufficient and scrutable basis for estimating relative risk and discriminating among alternatives.

A consistent database must also be applied. The WM PEIS includes options for consolidating waste from both new and existing sites and facilities. Current safety analyses, environmental assessments, and EISs provide much site-specific information, but they have been developed over many years as the underlying technology base and the related regulatory guidance have improved. The scope and

supporting levels of detail in site safety reports vary widely. Thus, a third objective was to support the data requirements for the implementation of the computational framework by appropriately combining existing documentation on the safety of facilities with the most recent guidance on accident modeling.

The last objective was to provide an automated capability to facilitate the overwhelming number of calculations in the accident analysis that are required to provide and evaluate the relative risk of the many combinations of process technology, facility selection, and site consolidation strategies in the WM PEIS alternatives for each waste type. The purpose is not only to provide baseline accident frequency and source term estimates, as required for the WM PEIS, but also to provide a capability for sensitivity analysis that can be used in the review process. Accident frequencies, radiological and chemical release source terms, and health effects on various populations are all sensitive to waste throughput. To allow accident risk to be characterized as a function of the throughput of a given waste type at each facility, thereby facilitating comparative evaluations, the requirements included integrating the computational packages of the accident analysis with the databases storing the data on the waste inventory and interfacing with the computer codes for health effects.

F.1.3 ANALYTIC APPROACH

To meet these objectives, an integrated approach was developed, which included the following interrelated elements: (1) selection of operations and related facility configurations across the DOE complex that have large and potentially hazardous inventories of radioactive or chemically toxic wastes vis-à-vis the attendant vulnerabilities and demographics of the facilities; (2) development and probabilistic evaluation of a uniform set of the risk-dominant sequences of accidents; and (3) determination of the evolution and final compositions of radiologically or chemically hazardous material source terms predicted to be released from these sequences. A personal-computer-based computational framework and database have been developed to automate these elements and to provide source term input for the analyses of health effects.

The source terms were subsequently used for assessment of the radiological or toxicological health effects and the risks of accidents to the general public and to the workforces. This assessment is discussed elsewhere (see WM PEIS Appendix D). In addition to source term development, the main elements in assessing risk include (1) development or integration of existing site-specific demographics and meteorologic data and calculation of attendant unit risk factors and (2) assessment of the

radiological or toxicological consequences of accident releases to the general public and to the occupational workforces by combining the source term and unit risk information.

Figure F.1-1 illustrates the integration of these elements into a systematic programmatic approach for performing risk impact analysis for the WM PEIS. The waste management alternatives discussed in the WM PEIS include the identification of siting options for storing and treating each waste type before disposal. Storage inventories and treatment throughput for each site affected by a given alternative are then defined by the current inventories, existing and projected waste generation rates, and the disposition of the waste. The volume and radionuclide composition of each waste are tracked in a relational database as the waste is processed to final disposal. Details of the method and computational framework developed to implement or link these elements for the accident analysis are described in Section F.2, with the remainder of this appendix discussing the accident analyses through source term generation for each waste type. The source terms for all accidents analyzed are provided in the technical support document (Mueller et al., 1995).

F.1.4 ORGANIZATION OF APPENDIX

Section F.2 describes the overall method and the integration of the computational components into a complete accident analysis framework. The section also describes the use and integration of generic and site-specific accident analysis data, with wastestream inventory data, storage and treatment process characterizations, and site and facility demographic information developed in the WM PEIS to provide a complete accident analysis data package.

Calculations with currently projected waste generation rates, storage inventories, and treatment process throughputs have been performed. Specific results are presented in this report for each of the waste-streams in the WM PEIS. Sections F.3 through F.7 summarize the accident analyses and aggregate the key results for each of the waste-streams. Frequencies and source term parameters are presented for each of the major DOE sites and facilities by consolidation alternative for each wastestream. Key assumptions in the development of the source terms are identified. Compilations of the chemical and radiological source terms for all of the accidents are provided in the report by Mueller et al. (1995).

The listed references include DOE orders and standards, U.S. Nuclear Regulatory Commission (NRC) regulations, and NEPA documentation, as well as technical reports developed in support of this regulatory guidance. The reference section also includes site-specific safety analysis and environmental

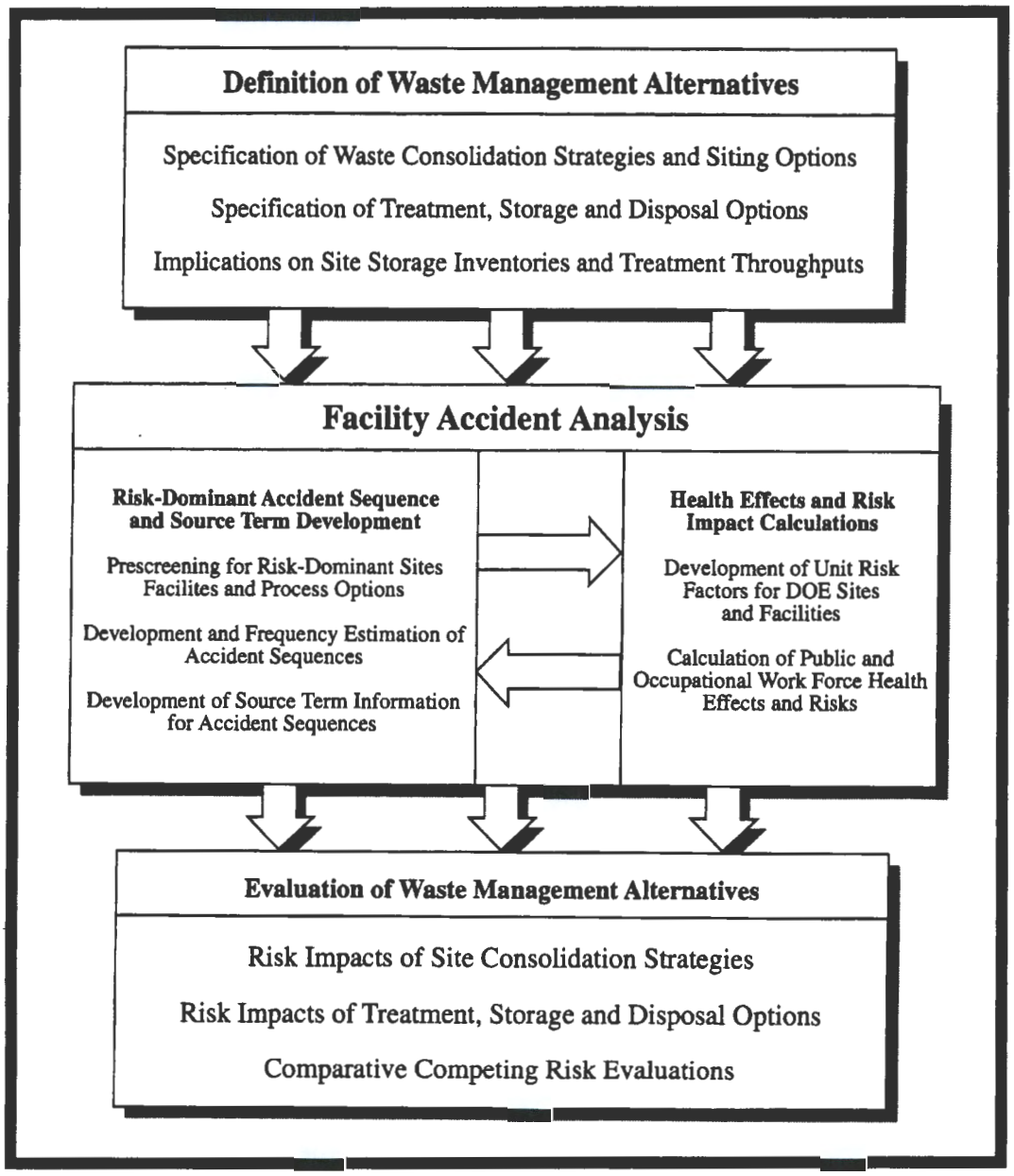

Figure F.1–1. Overview of Facility Accident Analysis Interactions for the WM PEIS.

impact documentation and related supporting technical reports that were used in support of the WM PEIS accident analysis.

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F.2 Methodology and Computational Framework for Accident Analysis

F.2.1 Overview

This section describes the methodology and computational framework for the facility accident analysis for the WM PEIS. Figure F.2-1 illustrates the major components, related input and output of data from the facility accident analysis, and an overview of the interactions of the analysis with other elements of the WM PEIS project. Implementation of this analysis included selection and development of the accident sequences and associated informational output for the source terms. Unit risk factors developed as part of the WM PEIS effort were used to screen accident sequences for risk dominance. A unit risk factor is a consequence associated with a unit release of a radionuclide to the environment from a facility or a given site for a given receptor.

This chapter is organized to reflect the integrated approach depicted in Figure F.2-1. Sections F.2.2 through F.2.4 explain how the illustrated program elements are applied to the WM PEIS accident analysis. The general discussion in the sections is applicable to the overall WM PEIS accident analyses for all waste types. Sections F.2.5 and F.2.6 discuss the general modeling assumptions and the data used to evaluate the frequencies for the various accidents and to determine the appropriate source terms for specific accidents, facilities, and waste types.

F.2.2 Selection of Risk-Dominant Operations, Facilities, and Related Types of Accidents

A review of the alternatives for WM was performed to focus the analysis of the large number of processes and facility configurations possible within the WM alternatives to address only those configurations with accidental radiological or chemical releases potentially important to overall risk and which may allow reasonable discrimination among alternatives. This section first describes the process of categorization and then describes the three classes of accidents selected: (1) general handling accidents, (2) accidents at storage facilities, and (3) accidents involving treatment processes and facilities.

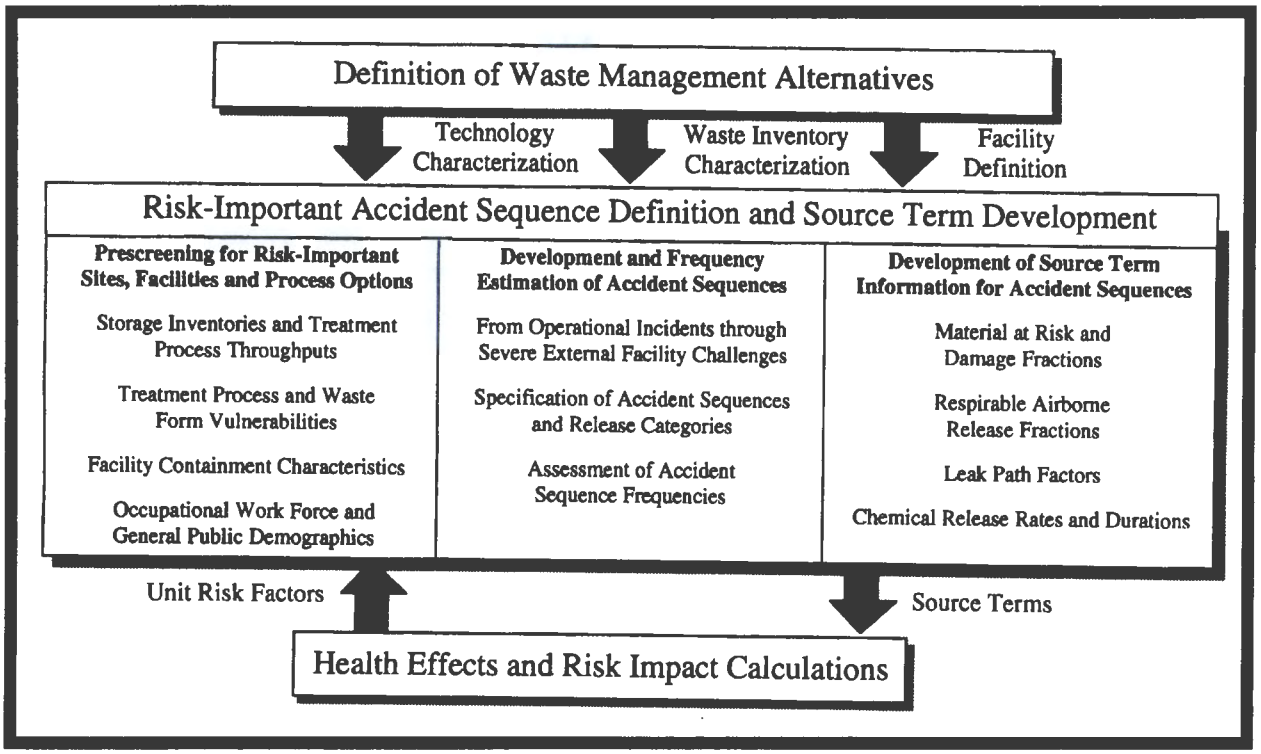

Figure F.2–1. Major Components and Related Input and Output of Data for Facility Accident Analysis.

F.2.2.1 Categorization and Screening

Waste management activities were categorized as falling within three operational regimes: (1) current or pretreatment storage, which includes placement in and retrieval from storage and transfer to facilities for pretreatment or treatment; (2) processing, which includes pretreatment (which applies only to HLW) and treatment; and (3) interim or predisposal storage. Because of the more stable nature of wastes in their final forms before disposal, the last operational regime was judged to pose a much smaller risk than current storage and processing. As a result, among the waste types, accidents affecting storage before final disposal were analyzed only for HLW.

Facilities considered in the WM PEIS also include operating and preoperational facilities and conceptual designs for facilities. The inventories in storage, the throughputs for treatment, and the sizing of the facility are all functions of the alternatives being investigated by the WM PEIS. Criteria were developed to help identify and classify potentially risk-dominant facilities and operations for each waste stream by their characteristics with respect to accidental radiological or chemical releases. These criteria included the amount and composition of the material at risk (MAR); the vulnerability of this

material to airborne releases; the containment characteristics of the facility; and the demographics of the operation, facility, site, and general population.

Only airborne releases were considered based on evidence in existing DOE safety analyses that airborne pathways dominate the accident consequences and drive the facility risks. Releases via surface runoff or to the ground cause longer term effects that are not a strong indicator of risk and would not be a strong discriminator for WM PEIS alternatives. The only reasonable threats that could cause immediate and appreciable effects via nonairborne pathways are large, stored volumes of HLW (tank farms). However, DOE has removed storage of HLW from consideration in the analysis, and releases via nonairborne pathways are not considered.

Amount and Composition of MAR. Each alternative for waste consolidation discussed in the WM PEIS implicitly defines unique pretreatment and posttreatment inventories and throughputs for treatment of each waste type at each DOE site. Specification of the storage inventories and treatment throughputs by volume, by physical and chemical form, and by radionuclide or chemical composition of the wastes was obtained from the WM database (Kotek et al., 1995). Accordingly, for each alternative for each waste type, the DOE sites were ranked by the curie and radiation hazard content of treatability categories for that waste type to determine those sites with the largest curie inventories of potentially risk-dominant waste. A similar review of ranking was done to determine sites with the greatest chemical inventories within the waste type (process chemical accidents that could not be strongly correlated with waste inventories or throughputs were not analyzed). These rankings led to the restriction of analyses for any given waste type to those sites with sufficient inventories to justify development of distinct source terms.

Vulnerability of MAR. A major focus of the screening was the vulnerability of the MAR to potential fire or explosion accident sequences. The physical and chemical stability of the waste was reviewed to preclude unnecessary analysis of storage or process operations involving highly stable wastes that would require extremely severe and improbable conditions to attain significant airborne releases. The packaging of the wastes and the overall configuration of the containment facility were also reviewed. As a result, only selected WM operations and treatment technologies were analyzed for source term development.

Characteristics of Facility Containment. Facilities considered in the WM PEIS range from outdoor storage pads with no capability for containment to facilities that have the structural capability to

withstand the forces from significant natural phenomena. The containment characteristics of the existing or proposed facilities were judged by their hazard category or natural phenomena hazards (NPH) performance category (PC) and the corresponding structural capabilities. This process led to the restriction of analyses herein to generic facilities with characteristics defined by their DOE Hazard Category. (Hazard category and NPH PC are discussed and defined in Section F.2.5.1).

Demographics. The hazard to the workforce is directly related to the radiological or chemical inventory involved in the accident, the number of workers affected, and the proximity of these workers to the point of release. Estimates of the population of workers for each treatment technology and facility were developed in the WM PEIS as a function of the throughput of the waste inventory to be processed. Consideration of these populations and their proximity to the point of release vis-à-vis the appropriate radiological or hazardous material inventories of the MAR provided an initial identification of those processes and facilities potentially dominating the risk to the worker population. The demographics for the general public were included as an input to the development of the health effects and risk impact analysis but were not specifically used to select accidents.

Review of the operations and facilities against these criteria led to the establishment of three broad classes of accidents as determined by their release characteristics and the facilities and populations affected. These classes include (1) general handling accidents involving a breach of the waste packaging, (2) accidents at storage facilities, and (3) accidents involving treatment (or pretreatment) processes and facilities. Within these classes, individual operations or facilities were then reviewed to better define potentially risk-dominant operations or facility configurations.

F.2.2.2 General Handling Accidents

General handling accidents were selected as a distinct class because hands-on operational accidents are expected to dominate the radiological and chemical risks to workers due to the relatively high frequency of such accidents and the proximity of the workers to any release. Such operations include handling in storage and staging areas, packaging and unpackaging, movement of waste within treatment facilities, and some treatment operations. These operations are prone to mechanical stresses in industrial accidents such as drops and spills of a container or punctures by a forklift, but the resulting breaches in a container can be shown to lead to insignificant airborne releases relative to those releases involving fires or explosions. As a result, these handling accidents usually constitute little hazard to the general public.

F.2.2.3 Storage Facility Accidents

Accidents at storage facilities were singled out as a separate class because they potentially involve large quantities of MAR. Moreover, because many storage facilities provide little or no formal containment or containment that would likely be breached in the event of severe thermal or structural challenges, severe accidents (such as fires) in a storage area may dominate the risk of releases to onsite personnel and the general population for many DOE sites.

Besides potential importance to risk two other criteria were used to determine which storage facilities and related accidents should be analyzed or reviewed: (1) potential for discrimination among PEIS alternatives and (2) quantity and quality of information available for guidance or input to analysis. As a result current storage (i.e. storage prior to treatment) of LLMW, LLW, and TRUW were not analyzed because the results will not help to discriminate among alternatives. This results from the underlying assumption used in the PEIS analyses that all sites will accumulate or at least not reduce these waste inventories for roughly ten years at which time complex-wide treatment will begin. Thus all sites will achieve their maximum inventories (leading to maximum potential releases), independent of alternative. Nevertheless, because recent DOE safety or NEPA information on storage facility accidents provides guidance on the potential risk impacts applicable to LLW, LLMW, and TRUW storage, this information will be discussed in the sections for these waste steams.

Calculation of the cost and risk impacts of current storage of HLW is not within the scope of the PEIS and as a result no analyses have been performed. However, the storage of vitrified HLW was analyzed because it could be a factor in discriminating among alternatives for HLW management. For the other waste streams, accidents were not analyzed for storage facilities housing solidified, vitrified, or otherwise highly stable wastes prior to disposal because of their low potential for risk-significant releases.

Finally, the characteristics of current or pretreatment storage for hazardous wastes do vary by alternative and accordingly, HW storage accidents have been analyzed and will be discussed.

F.2.2.4 Accidents Involving Treatment Processes and Facilities

Accidents involving treatment processes and facilities were identified as a separate class of accidents. Unlike storage accidents, where the overriding concern relates to the large amount of MAR, treatment

introduces different safety considerations such as the joint presence of high temperatures and pressures, combustible materials, and feed lines of natural gas or fuel. Moreover, the MAR may not only involve substantial inventories but may also have physical or chemical or highly concentrated toxicological or radiological characteristics that pose a threat to both the immediate workforce of the facility and the populations surrounding the facility. As a result, the facilities for treatment typically have containment structural design and filtration capabilities commensurate with these hazards.

Treatment operations were reviewed, and many were excluded from detailed investigation on the basis of the absence of a sufficient radiological and hazardous concentration or mechanistic stresses and energies capable of creating an airborne release likely to dominate the risk to either the work force or the public. These operations included evaporative processes and solidifying operations such as grouting and cementation (EG&G, 1992a,b). In general, benign operations, such as packaging and nonthermal size-reduction activities (including shredding, compaction, and supercompaction), were excluded from consideration as large-scale accidents. Technologies for mercury (Hg) separation were excluded because of their relatively low-energy operating characteristics. Thermal desorption of residues, sludges, and resins or of debris wastes involves combustible material; however, the process was excluded because it operates at lower temperatures and pressures than incineration, and the output product is much less dispersible than the ash from incineration.

Other high temperature or pressure processes were more closely reviewed in light of the potential energy source for dispersing airborne radioactive or toxic material and for challenging a facility's integrity and capability for filtration. Similarly, operations involving or being performed in the presence of combustible materials or involving feed lines of natural gas or fuel were reviewed in light of the potential for ignition and subsequent fire or explosions. Thus, thermal or heat-accumulating processes (such as fractionation by using ion-exchange columns, metal melting, incineration, wet-air oxidation, and vitrification) were identified for their potential for major airborne release. These processes are discussed subsequently.

Ion Exchange. Ion exchange is a standard technology for removing dissolved ionic solids, radionuclides, and toxic pollutants. Ions in an aqueous phase displace complementary ions from ion-exchange sites on the surface of an insoluble support material. Depleted resins are removed, replaced, or regenerated. Regeneration involves displacing contaminant ions with fresh complementary ions by washing with solutions of sulfuric acid or sodium hydroxide. The dominant accident considered in the literature is an explosion of the ion-exchange column, where self-heating of the ion-exchange resin

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results in fire or explosion, with attendant discharge of the radionuclide-loaded resin to the surroundings as a radioactive and chemically toxic aerosol. Abnormal conditions causing self-heating of the resin include introduction of a solution with a high concentration of nitric acid (which would result in a highly exothermic reaction), column overloading, presence of dry resin in the column, and high column temperatures (leading to ignition) (Ayer et al., 1988). This accident was predicted to have no impact on the operation of the ventilation system of the facility (Mishima et al., 1986).

Metal Melting. Metal melting is used to prepare, melt, and cast incoming scrap ferrous and nonferrous bulk metals. The incoming metal is shredded and transported to a furnace where it is melted and casted as ingots. Any combustible material in the incoming feed is thermally destroyed in a secondary combustion chamber. Highly radioactive materials tend to collect in the slag, which is skimmed from the top of the melt and casted into crucible molds. The cast slag is stored before final disposal, and the cast metal is sent to a fabrication plant for reuse into overpack containers and shielded caskets. The accident of concern is overpressurization and rupture of the combustion chamber with dispersal of the contents, particularly the radioactive slag.

Incineration. Incineration is a means of reducing the volume of combustible solid waste and destroying organic waste. Key characteristics of the incineration process with implications for potential airborne release include high temperature, the presence of combustible materials, the potential for rupture of the vessel, elevated concentrations of radioactivity in the ash byproduct, and the high dispersibility of the ash. Because incineration often results in a volume reduction factor of roughly 100, the ash byproduct could have a concentration of heavy-metal radionuclides roughly 2 orders of magnitude greater than the input feed waste. Accidents of concern for an incineration facility include explosions of the incinerator or fires involving the feedstock, ash residue, or residues in the filtration system. Feedstock fires may pose a toxicological risk for mixed wastes because of the relatively high concentrations of organics.

Wet-Air Oxidation. Wet-air oxidation is the aqueous-phase oxidation of suspended organic substances using elevated temperatures and pressures. Water (H_2O) catalyzes oxidation so that reactions proceed at much lower temperatures (175–340 degrees Celsius [° C] [347–644 degrees Fahrenheit (° F)]) than are required for oxidation in open-flame combustion such as incineration. Although the pressures (2–20 megapascals [MPa] [20–200 atmospheres (atm)]) are higher than those in other thermal treatment processes, the MAR is more dilute and is in an aqueous noncombustible liquid form. As a result, rupture of the oxidation vessel followed by a pressurized release is considered plausible but was judged

to be relatively insignificant in terms of radiological risk to the public or to occupational workforces and to be generally enveloped by incineration, a competing technology.

Vitrification. In vitrification, prepared wastes are mixed with glass-forming materials and transferred to the melter that converts the concentrated frit slurry feed into a molten liquid at a nominal temperature of 1,150 °C (2,100 °F). The final product of vitrification is a molten borosilicate glass. The key accident in vitrification is rupture of a vessel from a steam explosion due to the interaction of molten glass with water. This accident could affect the integrity of the cell in which the equipment is located (for example, shrapnel formation from the ruptured vessel) and damage to the off-gas filtration units and adjacent areas of the facility.

A comparative review of the characteristics of the identified treatment processes led to the selection of incineration as the technology most likely to dominate risk to the staff of the facility and the site, as well as to the surrounding general populations, for LLW, LLMW, TRUW, and HW. As discussed previously, the characteristics of radioactive release from wet-air oxidation are clearly enveloped by those for incineration, a competing technology. Nevertheless, because some of the treatment trains for LLMW sites have greater volumes of waste to be treated by wet-air oxidation than by incineration, source terms were developed as appropriate for tank ruptures with pressurized releases.

Although accidents with fractionation and with vitrification may be important in assessing pretreatment or treatment operations for HLW, these accidents do not affect WM PEIS decisions with respect to HLW alternatives. Vitrification of LLW incineration ash, of sludges and resins, or of wastes resulting from HLW partitioning is a process comparable to incineration in terms of temperature, potential for pressurization, and the combustible-material hazards. However, dispersibility of the feedstock would be equivalent to dispersal of the feedstock for incineration, and the forms of the vitrification material (molten and solidified borosilicate glass) would be less dispersible by several orders of magnitude than ash from a kiln or from a secondary combustion chamber (SCC). Similarly, the dispersibility of the contents of the radioactive slag in metal melting is also very low relative to the ashes in the incineration process.

In summary, source term analyses for treatment operations were generally restricted to incineration accidents, with a limited set of analyses performed for wet-air oxidation. Accidents associated with other types of treatment were generally not considered because of the arguments presented previously

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and because the throughputs for other treatment processes are generally low compared with incineration.

F.2.3 DEVELOPMENT OF RISK-DOMINANT ACCIDENT SEQUENCES

This part of the analysis involved the development of a framework that would accommodate the spectrum of accidents possible over the range of DOE facilities managing the different waste types. Orders, standards, and other regulatory guidance from the DOE, the NRC, and the U.S. Environmental Protection Agency (EPA), as well as key supporting documents, were reviewed to identify the spectrum of accidents, accident initiators, and potential releases routinely evaluated in safety analyses. The DOE *Defense Programs Safety Survey Report* (Pinkston, 1993) and other internal DOE reports related to the Idaho National Engineering Laboratory (INEL) and spent fuel EIS were also reviewed to provide guidance for the selection and evaluation of accidents. Finally, recent safety analysis reports (SARs) and other facility-specific analyses were reviewed for applicability to both specific facilities and related generic facilities.

Probabilistic risk assessment techniques were used to structure the computational framework for operational events and to track the progression of accidents for external events. Potential accident initiators were first reviewed and grouped into categories for analysis of subsequent accident progression (see Section F.2.3.1). A generic set of accident sequences was then developed to follow the progression of accidents into various source term categories organized by release characteristics and severity levels (see Section F.2.3.2). Nuclear criticality events were considered independently (see Section F.2.3.3).

F.2.3.1 Selection and Categorization of Accident Initiators

The selection of accident initiators was based primarily on the expected importance to human health risk of the potential radiological or chemical releases. Populations at risk include the workforce in the facility where the accident occurs, the population onsite, and the general population surrounding the site. In general, operational safeguards and equipment are in place to ensure that the impacts on the public health of all events are extremely limited, except in the most severe (and unlikely) accident situations. Higher frequency operational events, such as spills or drops, are expected to dominate the risks to workers; but the limited amount of material generally ensures that such events contribute little

risk to public health. The less-frequent severe accidents have large inventories at risk, and the potential exists for breaching multiple containment barriers and filtering systems and disrupting standard emergency procedures. As a result, the low frequency of such accidents is offset by their larger consequences; and, typically, severe accidents are predicted to dominate overall risks to public health. With different populations at risk, a spectrum of accidents covering a wide range of frequencies and expected consequences must be considered. The accidents considered meet the "reasonably foreseeable" criteria recommended by DOE (DOE 1993a).

To facilitate subsequent analyses, all generic accident initiators were first categorized on the basis of the nature of the initiator and the potential magnitude of releases. These categories included (1) operational events initiated from within the facility (internal events) and (2) external challenges to the facility. Internal events were subdivided to account for mechanically induced breaches of waste containers, fires, and explosions—all resulting from human errors, equipment failures, or industrial accidents internal to the facility. The external events were subdivided to consider accidents from (1) generally man-made events, such as aircraft crashes and fires and explosions onsite or at adjacent facilities, and (2) potentially catastrophic natural phenomena (for example, earthquakes, extreme winds or tornadoes, floods, and volcanoes) with likely implications for other facilities at the site.

These accident initiator categories were then mapped into the risk-dominant WM operations or facility configurations identified in Section F.2.2. The screening process used to intercompare the process and facility characteristics with generic accident consideration is illustrated in Figure F.2–2. Table F.2–1 shows the matrix of accident categories analyzed.

Finally, the accident sequences emerging from the initiators were categorized by the frequency classes traditionally considered in safety documentation (Table F.2–2). Risk-dominant accident sequences from each of the frequency ranges shown were assessed in a manner consistent with the recent NEPA (DOE, 1993a) guidance, in light of their potential for affecting different populations; however, accident initiators leading to sequences with nominal frequencies less than 1E–6/year (yr) were generally ignored unless (1) the predicted consequences were so high that the risk (product of frequency and consequence) was likely to be dominant or (2) the uncertainty in the estimated frequency of the sequence was so large that a significant chance existed that the true frequency was greater than 1E–6/yr.

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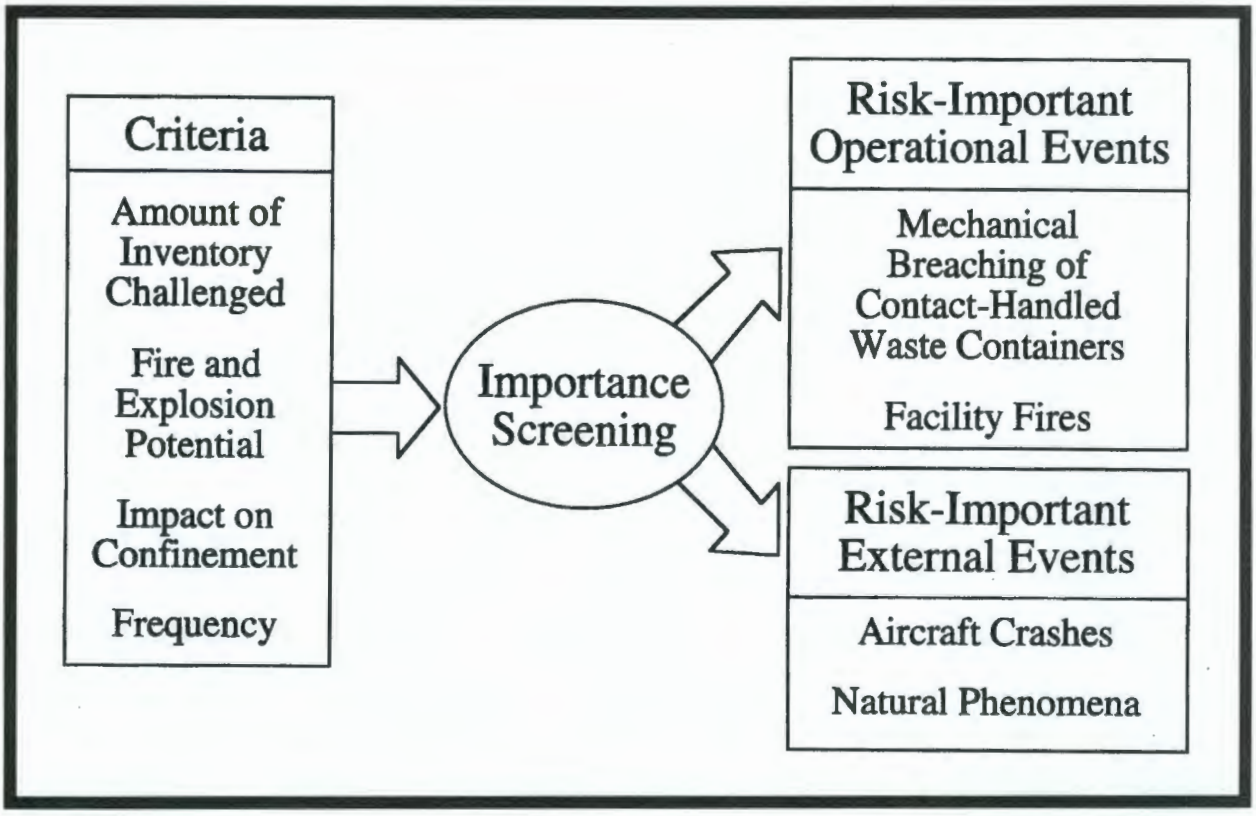

Figure F.2–2. Screening of Risk-Important Accident Sequences.

Table F.2–1. Risk-Dominant Accident Initiator Categories for WM Operations and Facilities

Function or Operation	Containment Characteristics of Facility	Internal Operational Accidents: Operational Branches of Waste Packaging	Internal Operational Accidents: Operating Fires or Explosions	External Challenges to Facility: Man-Made	External Challenges to Facility: Natural Phenomena
General waste-handling operations	Not relevant	X[a]	X	-[b]	-
Large-scale storage	Less than Hazard Category 2[c]	Included above	X	X	X
Treatment or pretreatment	Hazard Category 2	Included above	X	X	X

[a] X = risk-dominant accident initiator.
[b] Not applicable.
[c] See Figure F.2–4 for definitions of hazard categories.

Qualitative descriptions of the types of events comprising the accident initiator categories are found in Table F.2–3. Surrogate accident initiators were defined for the aforementioned subcategories of internal accidents on the basis of their expected frequency, dominant accident stress mechanisms, and potential

Table F.2-2. Frequency Classes Traditionally Considered in Safety Documentation

Frequency Class	Frequency (yr^{-1})	Definition
Likely	>1E-2	May be expected to occur once or more during the lifetime of the facility.
Unlikely	1E-4 to 1E-2	Not expected but may occur during the lifetime of the facility.
Extremely unlikely	1E-6 to 1E-4	Will probably not occur during the lifetime of the facility.
Not credible	<1E-6	Has extremely low probability of occurring.

consequences. Accident initiators were assigned frequencies appropriate to the process and facility configuration being evaluated, as reflected in the most recent safety documentation for DOE facilities managing nuclear waste and HW.

External event initiators for man-made challenges include impacts of aircraft and fires or explosions in adjoining or nearby facilities that would challenge the primary facility. Although the expected frequency of an aircraft impact is intuitively very low for most DOE facilities, certain facilities are located relatively close to airports or are in or near flight patterns for commercial, regional, or military airports. For these sites, aircraft crashes with attendant fires or explosions involving aviation fuel could dominate public risk. Impacts from small and large aircraft will have different frequencies and consequences and are considered independently. Frequencies for air crashes were derived (Appendix F of Mueller et al. [1995]) for each site from either site-specific documentation or generic guidance, depending on the proximity to airports and the exposure to flight patterns. Frequencies for fires and explosions were generally derived from generic data. Appendix C of Mueller et al. (1995) summarizes fire and explosion information used for guidance. Natural phenomena considered as external accident initiators included earthquakes, floods, extreme winds or tornadoes, and volcanic activity; however, source terms were not developed for catastrophic flooding accidents because subsequent significant airborne releases are both implausible and enveloped in magnitude by airborne releases resulting from other catastrophic natural phenomena in the same frequency range. This is especially true since liquid HLW storage is not included in the analysis.

Source terms were also not developed for volcanic activity because such activity is believed to pose a credible threat to WM facilities at only three major sites, the Hanford Site (Hanford), Los Alamos National Laboratory (LANL), and INEL. Eruption of the active volcanoes near Hanford or LANL

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Table F.2–3. Descriptions of Accident Initiators

Internal Operational Events (Generally with No Public Health Consequences)

Representative Industrial Accidents

Breach of primary containment of waste by an operational event, such as a handling accident, vehicular impact, improper system operation, system malfunction, or component failure, or eventuating from failure of a support system such as a loss of power. Breach of containment by a small fire or process explosions originating inside the facility are included. Large-scale fires from industrial accidents are also considered, independent of large-scale fires and explosions that challenge the facility from outside and which are treated separately. To the extent possible, initiation frequencies are taken or derived from information in the SARs or supporting documentation. Frequencies of fires and explosions accompanying or subsequent to the breach are based on the combustibility of involved materials or the presence of combustible materials within the facility and are conditioned on the frequencies of events precipitating the accident sequence.

Severe External Challenges to the Facility (Other Than Catastrophic Natural Phenomena)

Fire or Explosion

A fire or explosion originating outside the facility challenges the facility. Examples of initiators include explosions of fuel or volatile chemical tanks or trucks and fires impacting nearby facilities, fires in adjoining facilities, explosions of natural gas or process chemical lines or tanks, and naturally caused fires, such as prairie fires. If the facility is breached, concurrent (common cause) or subsequent accident events challenge the primary waste-containment barriers within the facility.

Impact of Aircraft

An aircraft or major aircraft component (engine) impacts the facility. If the facility is breached, concurrent (common cause) or subsequent accident events challenge the primary waste-containment barriers within the facility. The initiating frequency of impact reflects missiles posing a credible threat to secondary confinement and primary containment. Impacts from small and large aircraft will have different frequencies and consequences and are considered independently.

Catastrophic Challenges to the Site and Facility from Natural Phenomena

Earthquake

An earthquake exceeding the design basis for the facility occurs. Concurrent (common cause) or subsequent accident events challenge the primary waste-containment barriers within the facility.

Flood

A flood exceeding the design basis for the facility occurs. Concurrent (common cause) or subsequent accident events challenge the primary waste-containment barriers within the facility. Because subsequent significant airborne releases are both implausible and enveloped in magnitude by airborne releases resulting from other natural phenomena in the same frequency range, airborne source terms for flooding are not developed in this report. Dominance by airborne releases is especially true since liquid HLW storage is not included in the analysis.

Extreme Winds or Tornado

Extreme winds or tornadoes exceeding the design basis for the facility occur. Concurrent (common cause) or subsequent accident events challenge the waste-containment barriers within the facility.

Volcanic Activity

A volcanic eruption occurs, with ashfall or lava flow (or both). Breach of primary containment may be caused by an operational accident or malfunction due to loss of power or by impacts of structural failure due to heavy ashfall or lava flow. Concurrent (common cause) or subsequent accident events challenge the primary waste-containment barriers within the facility. Because volcanic activity is of concern at very few sites and because potential subsequent source term releases are either enveloped by analogous releases following other natural phenomena in the same frequency range or by the effects of the eruption itself, source terms from volcanic activity are not developed in this report.

Criticality

Nuclear Criticality

A nuclear criticality occurs within a storage facility or process vessel. Concurrent (common cause) or subsequent accident events challenge the primary waste-containment barriers within the facility.

would only result in ashfall, the potential effects of which are overwhelmed by analogous effects for earthquakes in the same frequency category. Although INEL is considered vulnerable to lava flow, the

airborne releases of radiological waste are expected to be comparable to those from large-scale facility fires. Thus, for the analyses herein, seismic events are analyzed as an enveloping scenario for floods and most volcanic activities, and large-scale facility fires envelop the lava flow accidents at INEL.

Seismic events are also used as the surrogate initiator for extreme winds or tornadoes, with the overriding reason being that standard atmospheric dispersion modeling would predict much greater dispersion (and hence greatly reduced airborne concentrations) for high wind conditions than for the stable wind conditions assumed to be present during earthquakes. Existing analyses in DOE SARs and in the DOE *Defense Programs Safety Survey Report* (Pinkston, 1993) show that seismic events generally bound the risks of winds or tornadoes, including the risks from wind-driven projectiles. With respect to such projectiles, unpublished preliminary analyses for TRUW drums stored on outdoor pads at the Savannah River Site (SRS) suggest that damage from projectiles could exceed damage caused by seismic events, primarily because of the stability of the drum-stacking arrangement and the lack of protection against projectiles. To appropriately bound potential damage by projectiles to unprotected outdoor storage areas, the damage for seismic events in the WM PEIS analysis is conservatively defined to have higher damage ratios than those used in the aforementioned SRS report in order to envelop the damage caused by high winds or wind-driven projectiles.

Frequencies of occurrence for natural phenomena were generally taken from DOE design and evaluation guidance regarding natural phenomena (see Appendix E of Mueller et al. [1995]); however, the frequencies of loss of integrity of a facility from the challenges of natural phenomena were determined in accordance with DOE facility NPH design performance goals, as discussed in Section F.2.5.1.

F.2.3.2 Specification and Evaluation of Accident Sequences

For the internal accident initiators defined in Table F.2–3, the plausible accident scenarios and the associated frequencies were based on existing accident analyses in SARs and EISs for DOE facilities. These existing analyses for DOE facilities with WM activities constitute a significant resource of information on accident assessment, and many of the analyses have been reviewed by peers and approved by the DOE. These analyses included scenarios that are very similar to those needed for the WM PEIS and that could be used to estimate accident frequencies. In many cases, the existing analyses included probabilities for failure that were based on experience or on data on plant failures. The use

of existing scenario frequencies precluded the need to estimate numerous event tree conditional probabilities for equipment failures and human errors that constitute the accident sequences.
High and low frequency estimates were taken from existing analyses for accidents with accident phenomenologies, facility types, hazardous material types, and circumstances similar to accidents considered in the WM PEIS evaluation. The frequency selected for the WM PEIS evaluation was based on the overall similarity of the existing analysis to the analysis in question. In some cases, adjustments were made to include or remove frequency contributions from preventive and mitigative features that may or may not be included in the WM PEIS alternative. In most cases, the frequencies used in the WM PEIS were toward the high end of the frequencies reported in existing analyses, as discussed in Section F.2.6.

For the external initiators, the analyses from existing SARs and EISs were sparse and often outdated. Because external events are rare, the facilities have no experience with direct impact of external forces or experience such as that of the nuclear Utility Seismic Qualification User's Group (SQUG); and analysis on the basis of experimental data could not be achieved. Event trees were developed to project the progression of the accidents associated with external initiators through plausible generic sequences. The extent of any release is a function of (1) the accident-related stresses affecting and rendering airborne the material involved in the accident and (2) the response of the containment barriers and filtration systems (if any). Accident stress mechanisms can be categorized as mechanical, fire-driven, or explosion-driven mechanisms; and branches of event trees were specifically defined to delineate fire and explosion categories for which experimental information is available to support the associated estimates of the release fraction.

The containment response is a function of the structural strength and operational status and efficiency of the buildings, equipment, and materials providing containment or filtering (or both), as well as the emergency response capabilities of the mitigative systems and relevant personnel. Accordingly, event tree branches were similarly defined to incorporate the key containment responses affecting the amount of airborne activity released to the atmosphere. This structuring of the event trees to incorporate stresses and responses of containment allowed a step-by-step characterization of the likelihood of the sequence and the magnitude of the release as the accident sequence progressed.

The accident sequences were developed and analyzed for categorical classes of facilities to (1) provide a uniform treatment of accident analysis to a wide range of facilities with similar design characteristics across the DOE complex and (2) reduce the number of actual analyses performed to a manageable

level. To implement this approach, existing facilities were generally mapped into a DOE-STD-1027-92 hazard category (DOE, 1992b) (see Section 2.5.1) and into DOE-STD-1021-93 facility NPH PCS (DOE, 1993b). In general, conceptual treatment process facilities were assumed to be hazard category 2. A no-confinement category was assigned to concrete pads used for packaged storage, weather protection sheds, Butler buildings, and facilities providing no real barriers to release, up to and including general-use buildings. This treatment is appropriate for catastrophic releases and conservative for more benign sequences.

A generic matrix of release characteristics was then developed as a function of the event tree branches to facilitate the tracking of potential source terms through the accident sequences. This approach enabled the determination of the fractional amount of each radionuclide or toxic chemical in the original inventory available for release (the airborne release fraction [ARF]) at each point in the progression of the accident. Each accident sequence is then terminated in a generic release category. This approach adapts the source term treatment used in the DOE *Defense Programs Safety Survey Report* (DOE, 1993f) to accident progression analysis (see Section F.2.4). The approach also allows the evaluation of contributions from both the accident initiation and the subsequent accident sequence to the damage and ARFs.

The final step in evaluation involved the integration of the radionuclide or chemical compositions of the waste process inventories of MARs in the accidents with the accident data to derive the source terms. Preliminary estimates of the effects on health were obtained by combining the information on source term with the unit risk factors for each site. With this information, a reduced set of risk-dominant source terms covering the plausible frequency spectrum was developed for final calculations on health effects and risk.

F.2.3.3 Nuclear Criticality

On the basis of existing safety analyses, criticalities are judged to be incredible for LLW and LLMW storage, treatment, and post-treatment storage. The safety analysis of the consolidated incineration facility (CIF) at the SRS (Du Pont, 1987) considered nuclear criticality as implausible on the basis of design basis feedstocks and as incredible on the basis of the large number of independent operator errors and other failures necessary to introduce an unsafe quantity of fissile material into the incinerator and processes. The numerous combinations of failures in the waste packaging, classification, and handling processes required to both introduce sufficient fissile material into an LLW or LLMW storage

or process facility and create a critical geometry or arrangement of the waste storage arrays simply rule out a credible criticality before or after treatment for these waste types.

Because the WM PEIS addresses only the shipping and interim storage options related to canisters of vitrified HLW, for which no plausible mechanisms exist to achieve criticality, source term analysis for HLW criticality is unwarranted.

A nuclear criticality in a TRUW solid-waste storage-and-handling facility (for example, Waste Receiving and Processing Facility [WRAP] Module 2 and the Radioactive Waste Management Complex [RWMC] [EG&G, 1993b]) is also judged to be incredible because of the low density and inventory of fissile material in the solid wastes, coupled with the dispersed geometry. Nuclear criticality can be conceived in some aqueous processing alternatives, depending on the dissolution of fissile material in the throughput of the process, the design of the vessel, and the flowsheet parameters (see Appendix C of Mueller et al. [1995]); however, this criticality would require numerous breakdowns of administrative and accountability controls or unforeseen design deficiencies in the processing system (or both).

The DOE requires specific analyses to estimate the frequency of criticality for such processes. If the analysis indicates credibility (>1E-6/yr), the DOE then requires specific design provisions to preclude or mitigate the effects. With these safeguards in place, accidents of nuclear criticality have been ruled out as not being sufficiently important to risk to justify source term analysis for TRUW and are not discussed further in this chapter.

F.2.4 Development of Source Terms for Accident Sequences

F.2.4.1 Radiological Source Terms

The method used to estimate radiological source terms is similar to that used in the DOE *Defense Programs Safety Survey Report* (Pinkston, 1993). The source term associated with each accident is the product of four factors that vary for each radionuclide within the inventory affected by the accident:

$$source\ term = MAR \times DF \times RARF \times LPF \ , \qquad \text{(F.2-1)}$$

where

MAR = material at risk,

DF = damage fraction,

RARF = respirable airborne release fraction, and

LPF = leak path factor.

Figure F.2-3 illustrates the evolution and development of the source term components from accident initiation through delivery to the atmosphere. While the disaggregation of the source term into these components broadly follows the treatment used in the DOE *Defense Programs Safety Survey Report* (Pinkston, 1993), the treatment of the components has been extended as discussed in Section F.2.3.2 to allow the tracking of these parameters at each point in the accident sequence.

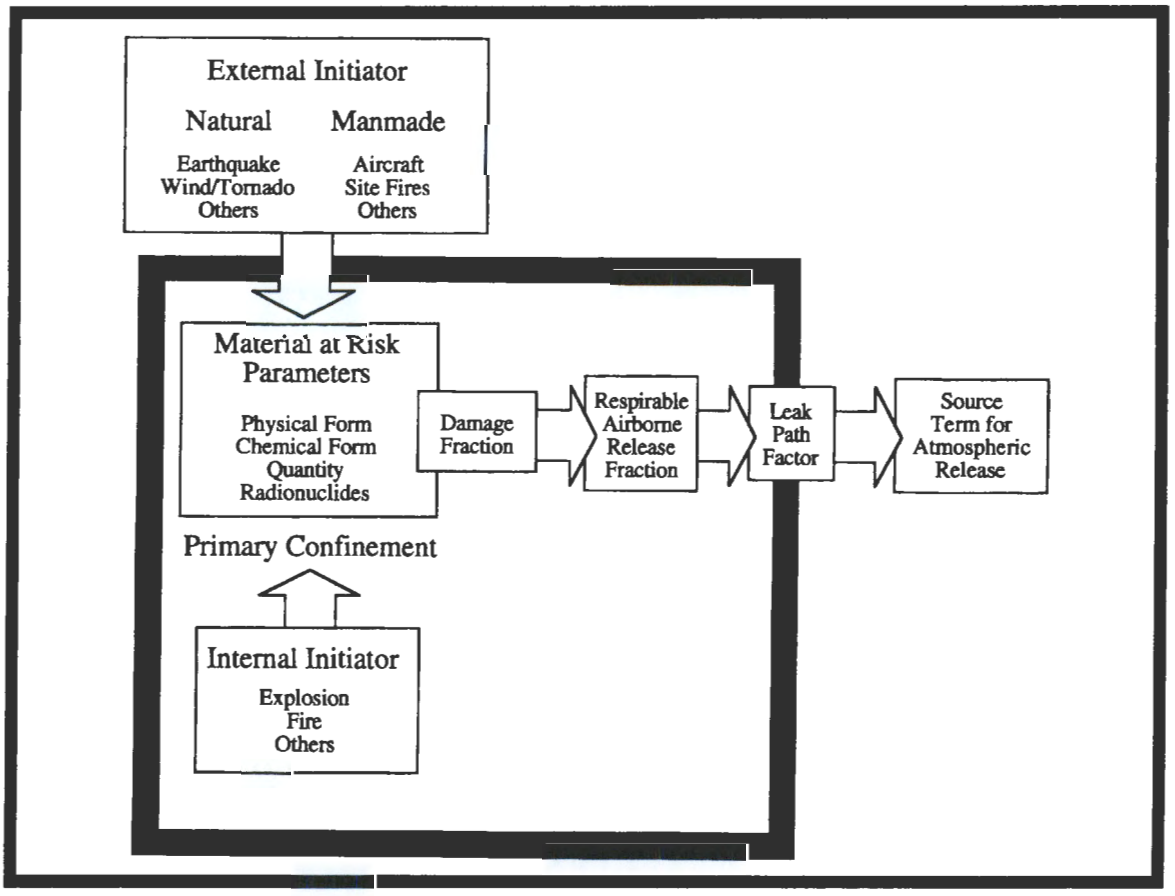

Figure F.2-3. Conceptual Flow Diagram for Source Term Development.

All accident sequences culminated in fractional release categories defined to accommodate the various combinations of generic sets of DF, RARF, and LPF. The source term release fraction (STRF) is defined as

$$STRF = DF \times RARF \times LPF \qquad \text{(F.2–2)}$$

and provides the fraction of each radionuclide or toxic material in the MAR that escapes the confinement and is available for atmospheric transport. This term, multiplied by the MAR, provides the source term used in the calculations of health effects and risk (see Section F.2.2).

F.2.4.1.1 *Material at Risk and Damage Fraction*

The MAR is the total inventory of waste in a facility or particular operation with the potential of being impacted. The MAR is a function not only of the configurations of the process and facility but also of the severity of the accidents challenging the process or facility; for example, catastrophic accident initiators such as earthquakes clearly have the potential to affect greater inventories of waste than do industrial accidents and thus have greater MARs.

The DF refers to the fraction of MAR involved in the accident sequence and actually susceptible to airborne release. The DF is a function of the severity of the initiator and is generally small for operational events if the MAR is large and larger for more severe events, such as external challenges to a facility from natural phenomena. The DF is also a function of the process and facility characteristics and of the subsequent phenomena encountered in the accident sequence, such as fires or explosions that have the capability of challenging or propagating to additional inventories of the MAR. More benign sequences without such mechanisms have sequence DFs that are zero or very small. Damage fractions were assigned as a function of the severity of the accident sequence, the physical and chemical forms of the MAR, and the vulnerability of the containment of the MAR.

F.2.4.1.2 *Respirable Airborne Release Fraction*

The ARF is the fraction of the potentially available inventory of the radionuclides rendered airborne at the point of the accident. The ARF is a joint function of the original physical form of the waste and

the accident mechanisms and concomitant stresses acting to create airborne materials. The airborne release of radioactive materials depends on the ability of an accident sequence to overcome the barriers between the radioactive material and the ambient environment and to subdivide and suspend the radioactive material. Liquids or solids must be either fragmented or deagglomerated and suspended. All materials in the gaseous state (noncondensable gases and vapors under ambient conditions) were assumed to be transportable and respirable. The ARF is also a function of the physical or chemical properties of the individual radionuclides or chemical species. The respirable fraction (RF) for particulates is conservatively defined as the fraction of particulates with aerodynamic equivalent diameters below 10 micrometers (μm). The aerodynamic equivalent diameter is the sphere of material with a density of 1 gram per cubic centimeter (g/cm^3) that has the same terminal velocity as the particle.

Many experiments and analyses have been conducted to provide both bounding ranges and best estimates of the release fractions of various radionuclides as a function of their chemical and physical form under a variety of accident stresses. The RARFs used in the accident sequences herein were derived by multiplying the ARF and RF for the applicable stress provided in DOE-HDBK-3010-94 (DOE 1994), which examines experimental data for the airborne release of materials under five types of stress: (1) explosions (shock and blast effects), (2) fires, (3) venting of pressurized liquids and powders (or venting of pressurized volume above solids), (4) crush-impact (either fragmentation by the impact of a falling hard unyielding object or the impact of a falling material on a hard unyielding surface), and (5) aerodynamic entrainment or resuspension. Where ARFs and RFs were unavailable for the type of material or the level of stress, values were derived by assessing the effect of some characteristic of the initiator or materials involved (for example, the effect of viscosity on the fragmentation and suspension of liquids in free-fall spill or pressurized release).

Matrices were developed for each waste type to account for the physical and chemical characteristics of the MAR by mapping the treatability categories into the physical forms for which airborne release data were developed. These matrices and results for the RARFs developed for the various physical forms of waste encountered in DOE waste management as a function of the stresses encountered in the potential accident sequences are shown in Mueller et al. (1995). This treatment allows the analyses of the stresses encountered in the initiating events and the accident sequences to be evaluated independently, which, in turn, allows the step-by-step buildup of the source term to be tracked and integrated with the response of the protection systems to facilitate calculations of health effects for both the occupational workforce and the public.

F.2.4.1.3 *Leak Path Factor*

The LPF is the fraction of the airborne inventory that passes through the containment barriers and filters to escape to the atmosphere. The LPF is a function of the physical form of the nuclide being released, the susceptibility of the nuclide to removal or reduction phenomena (such as precipitation or agglomeration) and to subsequent capture within the containment walls or filtering systems, and the effectiveness of the filtration systems in place. In-containment transport and filter effectiveness can be heavily dependent on the accident sequence, as well as on the structural characteristics and physical design of the facility. The LPFs were assigned on the basis of the integrity of the containment (if any) and the functionality of filtration systems in the facilities for the accident sequences. The more severe accident sequences generally involved breach of confinement, for which a conservative LPF of unity was assigned. Appendix D of Mueller et al. (1995) provides LPFs as a function of the effectiveness of the filters used in DOE facilities and the intracontainment transport properties of gases and particulates.

F.2.4.2 Chemically Hazardous Source Terms

Chemical source terms were specifically developed for two waste types: HW and LLMW. All accidents were divided into three general categories, each having subcategories and including sublethal and lethal end points:

- Spills resulting in partial vaporization of the waste ("spill only")
- Spills followed by ignition of the waste ("spill plus fire")
- "Other event combinations"
  - Spills followed by ignition of the waste and an induced explosion in a waste container ("spill plus fire plus explosion")
  - Facility fires resulting in a waste container breach ("fire only")
  - Mechanical failure of a compressed gas container resulting in an explosion ("spill and explosion")
  - Explosion from exposure of reactive material to air followed by fire ("fire and explosion").

The MAR and DF for the various chemical accident sequences were based on the same considerations as discussed for the radiological accidents.

In general, these accidents involve chemical or physical change in materials affected by the initial incident. The chemical and physical properties of the MAR were reviewed, and toxic gaseous products

were identified for the accident sequences. The masses of these products were estimated from the mass of the reactants and the stoichiometry of the reactions. Rates of releases were generally estimated by assuming exponential decay with time. Obviously, the exact course of an accident is shaped by a multitude of factors, including (but not limited to) temperature, humidity, pooling versus spreading of spills, the exact composition or concentration of reactive materials (often unknown), and the proximity and nature of nearby reactive materials (including packaging, shelving, and flooring). The details on the selection of the accident scenarios, on the chemistry involved in their progress, and on the estimation of the rates of release of the toxic gases are provided in the sections for HW and LLMW.

F.2.5 General Facility Modeling and Inventory Assumptions

As discussed in Section F.2.2.1, the accidents considered in the WM PEIS accident analysis include general handling accidents, storage facility accidents, and accidents involving treatment processes or facilities. To appropriately evaluate these accidents, descriptions and assumptions concerning the design and configuration of facilities must be established. This section discusses the generic DOE design and performance criteria and the design aspects and associated modeling assumptions that are the basis for the accident evaluation.

F.2.5.1 DOE Design and Performance Criteria

To understand how the facilities for TSD operations are affected by the various accident initiators discussed in Section F.2.3.1, an understanding of how DOE facilities are designed and evaluated is necessary. The DOE has established general design criteria (GDCs) for all types of facilities in DOE Order 6430.1A (DOE, 1989). The GDCs in DOE Order 6430.1A provide the minimum requirements for the design, construction, and maintenance of facilities; and these GDCs must be followed for all new construction, including modifications of facilities. For facilities constructed before 1989 (the year when the order was approved), similar predecessor GDCs were used, but compliance was less strictly enforced and the GDC were somewhat less stringent and specific. However, in the last few years, great emphasis has been placed on achieving compliance through facility upgrades or demonstrating that noncompliance with a particular GDC does not cause undue risk. An implied assumption exists throughout the WM PEIS accident analysis that WM facilities involved in all of the alternatives conform to DOE Order 6430.1A, including the requirements for a higher design pedigree (such as

control system redundancy or natural phenomena resistant design) for structures, systems, and components that perform a safety function.

The "graded approach" for facility design, as applied by DOE Order 6430.1A and other DOE orders and standards, is a particularly important design concept that affects the results and assumptions in the WM PEIS accident analysis. The graded approach is a common sense concept that the design pedigree, as well as the operational maintenance and surveillance, for structures, systems, and components should be commensurate with the importance that the structures, systems and components have with respect to the protection of the onsite workers, the public, and the environment. To achieve the appropriate design pedigree and to select appropriately stringent criteria from DOE Order 6430.1A, the DOE classifies facilities by using criteria in DOE Standard DOE-STD-1027-92 (DOE, 1992b). This standard categorizes nuclear facilities into hazard categories 1, 2, or 3 on the basis of the effects of unmitigated releases of hazardous materials. Category 1 facilities are the most hazardous and are considered to have the potential to cause significant offsite effects. Category 3 facilities are the least hazardous and do not have the potential to cause offsite effects or more than minor onsite effects. Analogous categories for nonnuclear facilities (no radiological hazards) are also established and are referred to as high-, moderate-, or low-hazard facilities.

It is reasonable to assume that the safety significant aspects of the facility design (i.e., those that may affect the PEIS analysis) comply with the GDC since compliance must be demonstrated as part of the authorization basis for facility operations. As such, noncompliant features that may threaten the safety envelope documented in the authorization basis are reviewed for their safety impact and modifications and retrofits are made as necessary. The GDC are also considered in the safety review of design changes to ensure that compliance is achieved, and the authorization basis is maintained. Facility compliance to the GDC ensures the facility safety envelope is maintained and assuming GDC compliance for the PEIS accident analysis is reasonable and justified.

An assumption or assertion that a facility is in a particular hazard category implies that the facility has a design pedigree commensurate with the level of risk posed by the facility. However, the assumption of a higher design pedigree does not in itself ensure that risks to the public and workers are appropriately controlled. The assumption of a design pedigree simply implies that structures, systems, and components are designed to prevent accidents or to mitigate the consequences accidents. The assessment that risks are adequately controlled is documented in safety analysis documentation that uses

risk-based methods to demonstrate that appropriate programmatic functions and controls are used in concert with the facility design to achieve acceptable risk performance.

To achieve a performance goal of not exceeding a certain annual probability of loss of function in a facility, the facility (and related structures, systems, and components) must be designed to withstand a certain magnitude of hazard (the design basis natural phenomena event). Report UCRL-15910 (Kennedy and Short, 1990) provides guidelines for selecting the natural phenomena design basis and the maximum acceptable annual probability of exceedance of the hazard to achieve a predetermined performance goal for a facility. In the WM PEIS, a facility of a particular hazard category is assigned a performance goal as defined in DOE-STD-1021-93 (DOE, 1993b). The design basis hazard magnitude for earthquakes and winds corresponding to the hazard annual probability of exceedance (listed in UCRL-15910) is obtained from site-specific hazard curves reported in the Natural Phenomena Hazards Modeling Project (Coats and Murray 1984). For example, for a Hazard Category 2 facility, the performance goal is 1.0E-04; and based on UCRL-15910, the recommended maximum annual probability of exceedance of a seismic hazard to meet such a performance goal is 1.0E-03. Thus, for a given site such as ANL-E, the peak ground acceleration corresponding to an annual probability of exceedance of 1.0E-03 is 0.12 g (Coats and Murray, 1984), where *g* is the gravity acceleration. Therefore, a Hazard Category 2 facility at ANL-E with a 0.12 g seismic design basis has an annual probability of exceedance (beyond seismic design basis) of 1.0E-03 and an annual probability of loss of function of 1.0E-04 (beyond performance goal).

Figure F.2–4, abstracted from DOE-STD-1021-93 (DOE, 1993b), depicts the performance goals of 1E–5, 1E–4, and 5E–4 assumed herein to represent frequencies of facility containment failure under challenge from natural phenomena for Hazard Category 1, 2, and 3 buildings, respectively. This figure also shows the relationship between the criteria of resistance to natural phenomena and the PCS and performance goals. The DOE orders and standards to implement the use of these criteria, including DOE Orders 5480.23 (DOE, 1993e), 5481.1B (DOE, 1987), 6430.1A (DOE, 1989) and 5480.28 (DOE, 1993c; formerly 5480.NPH), are also shown. The primary DOE standards for performing structural design and evaluation with respect to natural phenomena resistance are DOE-STD-1021-93 (DOE, 1993b) and DOE-STD-1020-92 (DOE, 1993d), formerly UCRL-15910 (Kennedy and Sport, 1990). Although some of the concepts in these standards are still in draft form and have not been approved for use by the DOE, the approval process is well along; and no changes large enough to affect the results of the WM PEIS accident analysis are anticipated.

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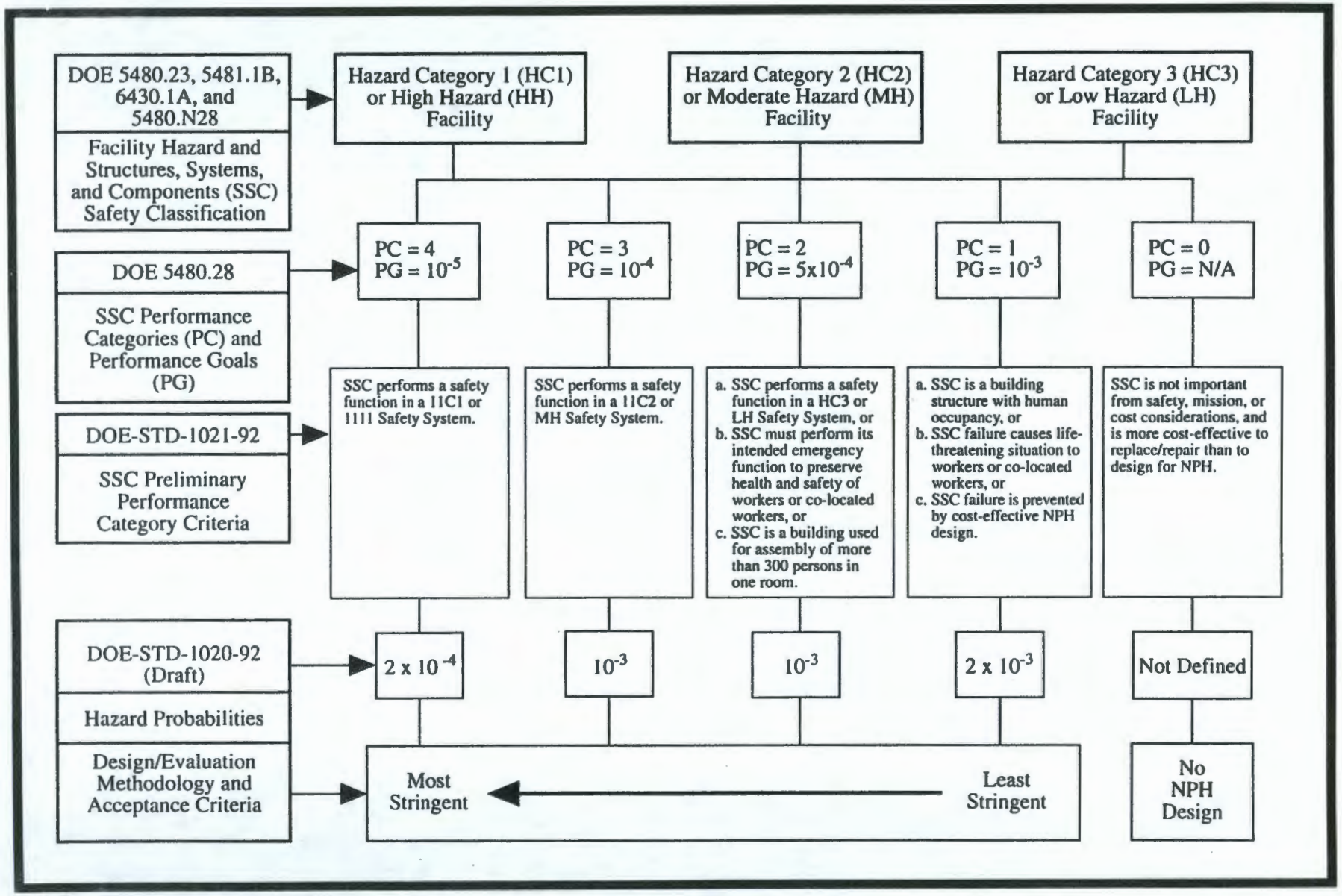

Figure F.2–4. DOE Performance Goals for Hazard Category 1, 2, and 3 Facilities (DOE, 1993b).

In general, the facility categories referenced in the WM PEIS analysis refer to the hazard category that is established by using criteria from DOE-STD-1027-92 (DOE, 1992b). Most of the facilities considered in the WM PEIS alternatives are Hazard Category 2 or 3 or general-use facilities. Treatment facilities were assumed to be Hazard Category 2 for accident analyses. Storage facilities were conservatively assumed to have no containment.

F.2.5.2 Storage Facility Accidents

LLW, LLMW, and TRUW. The underlying assumption used in the PEIS is that all sites will accumulate or at least not reduce these waste inventories for roughly ten years at which time complex-wide treatment will begin. Thus all sites will achieve their maximum inventories (leading to maximum potential releases), independent of alternative. As a result of not discriminating among alternatives, accidents for current storage of LLMW, LLW, and TRUW were not analyzed. However, to provide guidance on the likely impacts of storage facility accidents, a review of recent DOE NEPA guidance or safety documentation is provided in the individual sections for LLMW, LLW, and TRUW. Although not relevant in the discrimination of PEIS alternatives, this guidance facilitates qualitative comparisons of the relative impacts of storing wastes in their current form versus treating these wastes prior to disposal.

Current storage for these waste streams is accomplished in a variety of ways. Low-level waste is generally packaged in drums or containers and stored on outdoor concrete or asphalt pads or in weather-protective sheds pending treatment or shallow land disposal. Low-level mixed waste is generally packaged in drums or containers and stored in Resource Conservation and Recovery Act (RCRA)-compliant weather-protective sheds pending treatment. Transuranic waste is generally packaged in drums or containers and stored in concrete structures, in weather-protective sheds, in earthen berms, or in below-grade caissons (remote-handled [RH] TRUW). Most contact-handled (CH) TRUW, which dominates the total TRUW inventories, is stored in facilities with minimal containment, although DOE sites are moving toward qualified TRUW storage.

High Level Waste. Most DOE HLW is stored in large underground tanks at Hanford and Savannah River with much smaller amounts stored at INEL and West Valley. Because calculation of the cost and risk impacts of current storage of HLW is not within the scope of the PEIS, no analyses of these storage facilities were performed. However, the storage of vitrified HLW was analyzed because it could

be a factor in discriminating among alternatives for HLW management. These analyses are described in the section on HLW.

Hazardous Waste. Hazardous waste is generally packaged in 208-L (55-gal) drums and stored in RCRA-compliant staging areas or weather protection sheds before offsite shipment for commercial treatment and disposal. A HW storage facility (HWSF) typically has over 100 different chemicals, which may include chlorinated solvents, acids, bases, photographic chemicals, ignitable solids and liquids, compressed gases, metallic salts, lab-packed wastes, polychlorinated biphenyls, asbestos, and other regulated wastes. With explosives generally prohibited, the potential hazardous characteristics include volatility, flammability, dispersibility, and toxicity; and the HW is characterized and segregated on the basis of toxicity, corrosivity, reactivity, and ignitability. Most HWSFs have containment berm areas and individual storage cells that permit waste segregation according to RCRA and EPA criteria; some HWSFs have the capability of fire detection and suppression, and some have forced ventilation.

Because of the great diversity of storage facility designs among the DOE sites, a generic facility configuration with design characteristics such as storage arrays and segregation (as illustrated in Figure F.2–5) was assumed in the analyses. No credit was taken for containment or filtration.

F.2.5.3 Treatment Facility Accidents

The configuration of the generic treatment facility for the WM PEIS accident analysis consists of a series of linked process modules, each providing a specific treatment process. Modules providing common service to the process modules consist of (1) front-end support, providing waste receipt and lag storage; (2) treatment receiving and inspection; (3) container open, dump, and sort; (4) certification and shipping; and (5) back-end interim storage before disposal. Process modules consist of specific treatment operations and process support services. The treatment facility is assumed to consist of process trains for both RH and CH operations, with similar unit operations, differing only in the degree of shielding and the degree of contact operations and maintenance. The RCRA contaminant removal technologies entail modules for (1) sorting and segregation (for example, before incineration); (2) removal or destruction of aqueous organics before evaporation; (3) metal removal; (4) metal recovery; (5) Hg removal and recovery; and (6) stabilization of various waste constituents by immobilization, conversion to stable forms, or removal.

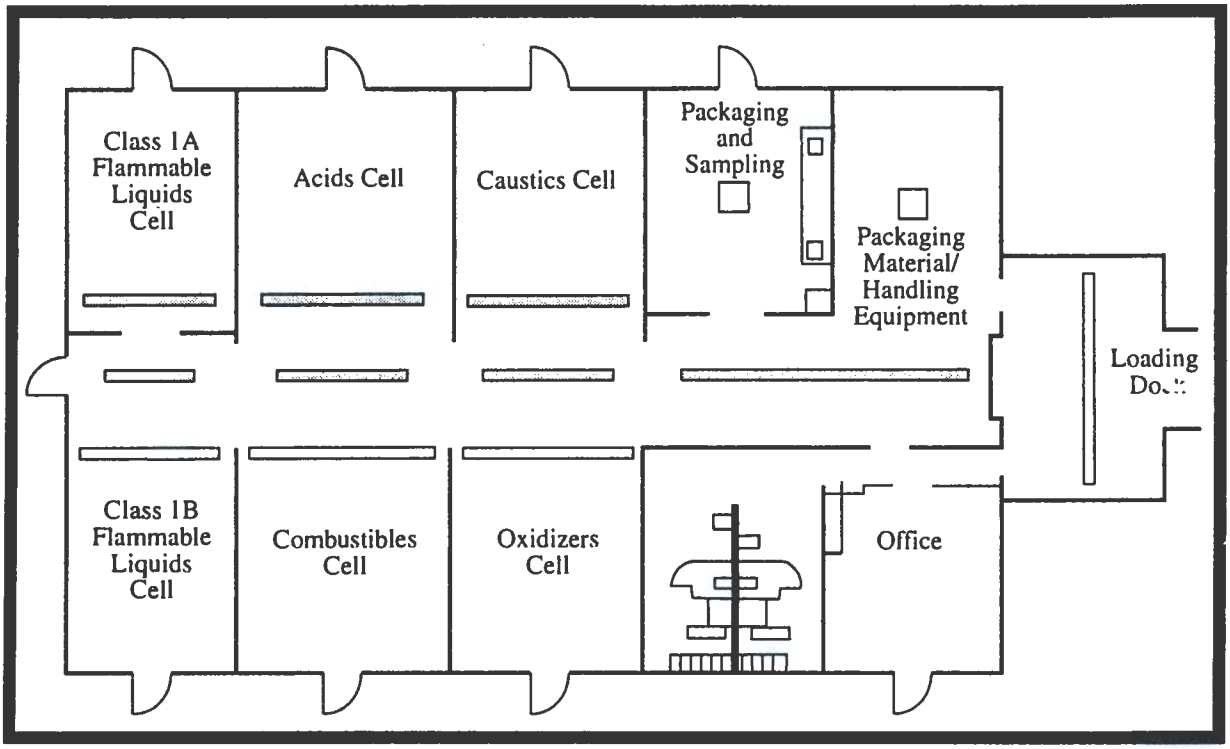

Figure F.2-5. Typical Design for Hazardous Waste Storage Facility.

As discussed in Section F.2.2.4, a generic incineration facility was selected for the evaluation of LLW, LLMW, and TRUW accidents. The RH and CH incineration portions of the facility shown in Figure F.2-6 have the following general functional areas: a receiving, storage, and feed area; the incinerator area, housing the rotary kiln and an off-gas secondary combustion chamber; an incinerator off-gas treatment area; a liquid treatment area; a solidification area (when cement solidification is applied to the ash); and facility and process exhaust air treatment, including the high-efficiency particulate air (HEPA) filtration systems. The receiving and storage area contains waste in various (but mostly solid) physical forms. Waste is fed to the incinerator after preparation (sorting or shredding, or both, as required). All combustible materials are destroyed, leaving a solid (ash) residue. The ash is generally solidified or packaged (or both) before transportation and disposal.

Incineration off-gas treatment includes a condenser and fume scrubber and generates a liquid wastestream of condensate and spent gaseous scrubber solution. In the liquid treatment area, dissolved and suspended solids are removed, liquid residue is prepared for immobilization, and treated wastewater is recycled to the system. In the solidification system, the sludge from the liquid residue

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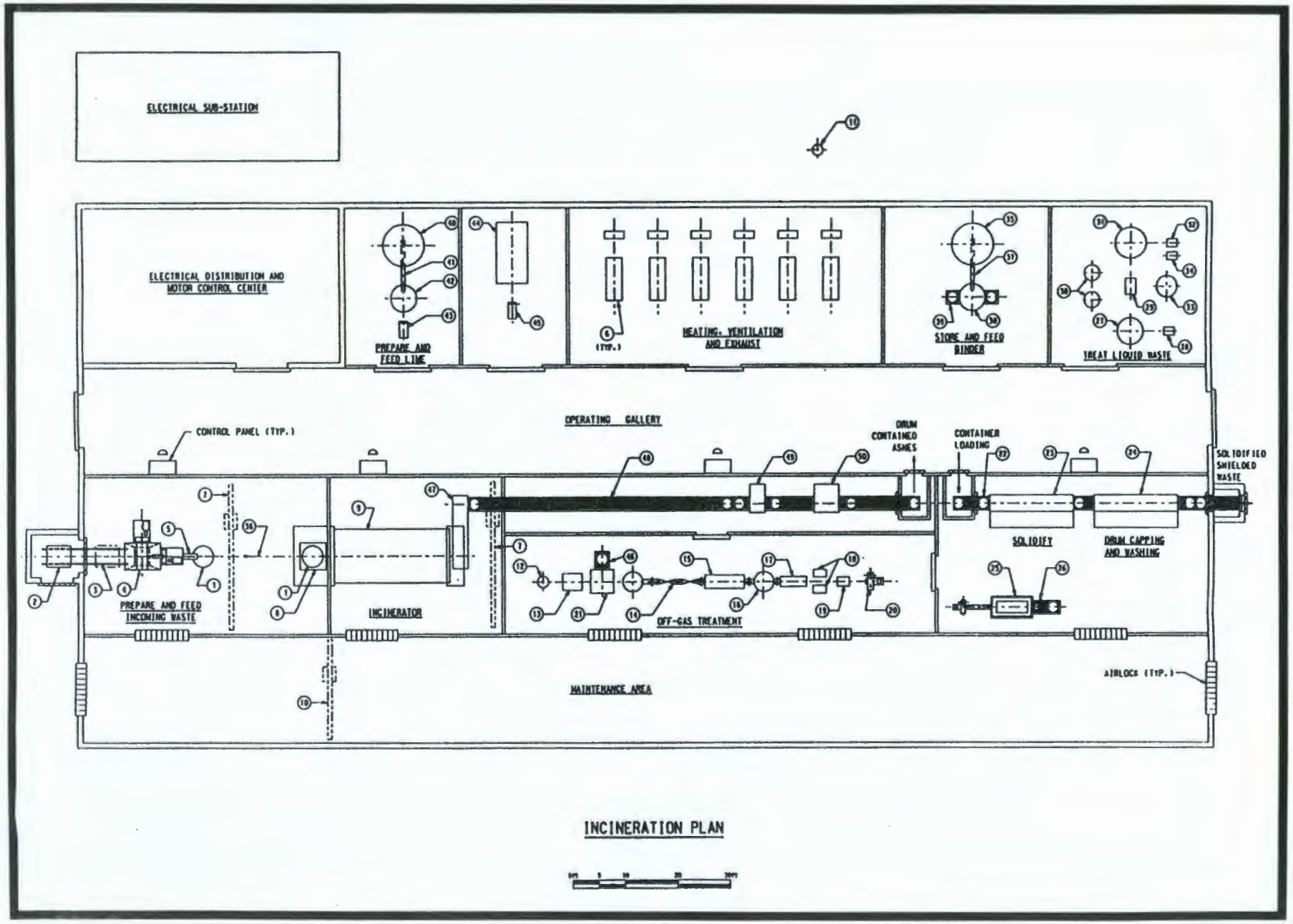

Figure F.2–6. Plan View of Incinerator Facility.

Figure F.2-6. Key to Equipment.

1 = Waste Transfer Bin
2 = Incoming Waste Bin
3 = Skip
4 = Shredder 2 With Feed Hopper, Dust Hood, and Hydraulic Ram
5 = Auger Feeder
6 = HEPA Filter and Fan
7 = Underhung Crane in Enclosed Process Area
8 = Feed Bin
9 = Incinerator
10 = Underhung Crane in Enclosed Maintenance Area
11 = Stack
12 = Afterburner
13 = Cooler
14 = Double Venturi
15 = Condenser
16 = Mist Eliminator
17 = Reheater
18 = Double HEPA Filters
19 = Final HEPA filter
20 = Interior Decontamination Fan
21 = Ceramic Bag Filter
22 = Drum Staging Conveyer (Powered Roll)
23 = Solidification System
24 = Drum Capping and Washing System
25 = Dust Collector, Fan, and HEPA Filter
26 = Drum Staging Conveyor (Powered Roll)
27 = Receiving Tank
28 = Pump
29 = Filter
30 = Ion Exchange
31 = Treated Waste Tank
32 = Pump
33 = Sludge Tank
34 = Pump
35 = Storage Bin
36 = Bin Hoist
37 = Conveyor
38 = Day Bin
39 = Drum Staging Conveyor (Gravity)
40 = Lime Silo
41 = Screw Conveyor
42 = Mixing Tank With Mixer
43 = Feed Pump
44 = Chiller
45 = Circulation Pump
46 = Drum Staging Conveyor (Powered Roll)
47 = Drag Conveyor
48 = Drum Staging Conveyor (Powered Roll)
49 = Capping Device
50 = Washing Device

and the ash resulting from the incineration are mixed with concrete and immobilized. Waste in the other areas is in the form of ash. In the CIF at the SRS, wet ash is found in all ash areas except the two combustion chambers (Du Pont, 1987). Dry ash is generated in other DOE incinerators and, because of its greater dispersibility, is assumed here for source term development.

The incineration facility also produces a residual gaseous wastestream. The incinerator off-gas treatment unit is designed to remove particulates, sulfur dioxide (SO_2), hydrogen chloride (HCl), and nitrogen oxides (NO_x). The off-gas from incineration contains carbon monoxide (CO), SO_2, and NO_x. Acid gases are typically removed by scrubbing. Radioactivity and some toxic metals are released directly in off-gas as volatilized compounds and radionuclides (iodine, ruthenium, and cesium) or radioactive gases (carbon dioxide [CO_2], H_2O, and SO_2 formed with carbon 14, tritium [^3H], and sulfur 35, respectively). Some fission products are also released indirectly in combination with particulates that are removed by off-gas scrubbing and filtering.

Detailed modeling of facilities was beyond the scope of the WM PEIS. Accordingly, a treatment facility with generic confinement characteristics defined previously was used to assess accidents to envelop the releases from accidents in the treatment process. A DOE Hazard Category of 2 and the associated performance requirements on its systems were assumed. Double-HEPA-filtration structures, systems, and components were assumed to be in place. The waste inventory at the time of the accident was based on the facility throughput at each site and included unique volumetric inventories and physical, chemical, and radiological compositions for each site for each alternative.

F.2.6 Evaluation of Source Term Parameters and Frequencies

This section discusses the development of the frequency and source term data generally used across the waste types. The evaluation of the frequencies and source term parameters required not only generic data applicable to broad classes of accidents but also data specific to the various waste types to account for differences in the physical and chemical forms, the packaging used as primary containment, and the facilities used to store or treat that waste type. The final selection of data used for facility accidents for each waste type is discussed in further detail in the chapters describing the analyses for that waste type.

Following the generation of these data, a number of new or previously unavailable accident analyses addressing facility accidents have been obtained that were performed in support of recently published

DOE Safety Analysis Reports (SARs) and EISs. Another new document of particular relevance that has just been published is the new DOE Standard (DOE-HDBK-3010-94, December 94) on respirable airborne release fractions, (RARFs), which provides the latest RARF values published by DOE for use in accident analysis. These latest values supercede some of the RARF values used herein. At the time of this writing, these reports were being reviewed to determine whether they would significantly affect the source term calculations or frequency assignments developed herein. Review to date suggests that the assumptions used for the PEIS accident calculations tend to lead to somewhat more conservative releases than would be calculated using the most recent DOE guidance as a guide.

F.2.6.1 General Handling Accidents

The dominant contributor to worker risk from radiological or chemically hazardous releases is expected to result from mechanical breaches of waste containers in handling accidents. This expectation stems from the relatively high frequency of such occurrences and the proximity of the worker to the point of release in such operational incidents. Handling accidents include container breaches caused by package drops, by forklift or other vehicular impacts, by crane drops or crushing, and by overpressurization. The use of heavy equipment poses a potential for damage to waste packages either because of package handling or inadvertent collisions. For many facilities, such as WRAP (DOE, 1991b) at Hanford and the RWMC (EG&G, 1993b) at INEL, cranes are used to move drums and boxes, with the height of movement generally exceeding the nominal 1.2-meter (m) (4-feet [ft]) height design specification for drum drop (Type A package; Code of Federal Regulations [49 CFR Part 173]) integrity. In all facilities, crushing of drums or boxes caused by impact with trucks, forklifts, and other equipment is possible. Although one waste container would generally be breached in an accident, rupture of multiple containers could occur in instances when several containers are handled at a time.

Treatment processes entail minor hazards to the operating staff, including puncture wounds during waste sorting, minor contamination from glove failures, and minor spreads of contamination from the events of treatment equipment pressurization and from off-gas treatment confinement failures (corrosion, gasket failures, etc.). The risk from exposure to radiation from these operational incidents is judged to be enveloped by the analysis for general handling accidents herein.

The frequencies for chemical spills involving HW or LLMW are derived by using site-specific inventories of individual representative chemicals, along with the assumptions identified previously on

the frequencies of breach per operation. Conditional probabilities of fire or explosion of chemically reactive or combustible chemicals are also developed. These discussions are included in the sections on HW and LLMW accident analyses.

Evaluation of Source Term Parameters. For fall or crush damage scenarios in operations with stacked arrays, the MAR will generally vary from one to four packages, depending on the method of stacking and the arrangement of the array. Storage packages are typically (1) Type A (49 CFR Part 173) plastic-lined, carbon steel 208-L (55-gal) drums; (2) plastic-lined wooden boxes (120 centimeters [cm] × 120 cm × 210 cm [4 ft × 4 ft × 7 ft] or 60 cm × 120 cm × 210 cm [2 ft × 4 ft × 7 ft]); (3) TRUPACT-II standard waste boxes (metal boxes measuring 120 cm × 120 cm × 210 cm [4 ft × 4 ft × 7 ft]; or (4) ST-5 metal boxes (120 cm × 120 cm × 180 cm [4 ft × 4 ft × 6 ft]). The Waste Isolation Pilot Plant (WIPP) final SAR (DOE, 1990b) assumes that 25 percent of the package contents are spilled (that is, a DF of 2.5E-01) for events dislodging the drum lid and that 10 percent of the waste package(s) are inadvertently punctured with forklift tines.

In the majority of handling accidents or hands-on processing incidents, the MAR would be limited to a single package. For more severe sequences involving an array of several containers being dropped or impacted in a single accident, the MAR would depend on the configuration but would be limited to the maximum number of packages in the array. Because the accident releases of greatest overall risk to the workforce involve single-drum handling operations where the worker is in contact with or very near to a breached package, a MAR of one drum is specified to calculate source terms for general handling accidents for all waste types.

The DF of the MAR subjected to spill, crush-impact, or overpressurization would depend on the location of the breach, the physical form of the MAR, and the severity of the accident stress. Liquids and volatiles would be free to flow out of a breached container, whereas most solid material would remain inside. Breached containers of LLW, LLMW, and TRUW are assumed to hold solid wastes, with a single-container DF of 2.5E-01. Breached containers of HW are assumed to hold liquid, with a single-container DF of 1E+00 for the representative handling accidents analyzed herein. The physical and chemical composition of the MAR in storage was defined by weighting the relative treatability category inventories at each site.

Evaluation of Frequencies. Numerous frequency estimates for waste package breaches in a facility are reported, although facility inventories are generally not reported in existing safety analyses. The SAR for the RWMC (EG&G, 1993b) estimates an annual frequency of external drum breach of 1.4E+00/yr per facility. The EIS for new production reactor capacity (DOE, 1991a) estimates a total annual frequency of externally induced drum breaches of 2E-02/yr and a rate of vehicular crashes of 1.8E-02/yr. Published joint probabilities for a drop from a crane and for the drum or container to breach range from 1.2E-01 to 8E-02/yr per facility. The various WRAP studies (DOE, 1991b,c; WHC, 1991a,b) assume that 10 percent of dropped containers are breached. A low value (8E-02/yr) has been estimated for damaging packages during loading drums into TRUPACT containers, which is similar to an estimate for breaching drums during ATMX railcar loading (1.1E-01/yr). A higher value of 1.2E-01/yr was estimated for damage during the retrieval and re-storage of buried TRUW drums and boxes at INEL (DOE, 1992a). This value is assumed to be more applicable to TRUW because of the large number of package movements required in the operations of the storage facilities. A frequency of 7.5E-02/yr has been estimated for puncturing up to two packages with forklift tines or, in some fashion, damaging one or more waste packages during heavy equipment operation (for example, dislodging the top tiers of a four-package-high array).

The approach used herein was to develop an estimate of the frequency of mechanical breaches for general handling operations on a per-operation basis, with an operation defined as picking up, moving, and setting down a container. The SAR for the HWSF (EG&G, 1990) uses an estimated frequency of one drum breached per 10,000 operations, on the basis of analyses at the Rocky Flats Environmental Technology Site (RFETS). A fault tree analysis of container rupture at the HWSF resulted in a probability of 3E-03 of an operation error, with a conditional probability between 2E-03 and 1E-02 for drum breach after an impact, depending on the type of container, or 1E-01 for drum piercing. Although several handling errors are considered, this analysis leads to a frequency of rupture between 6E-01 and 3E+00 for every 10,000 operations. The WIPP fire hazards analysis (Westinghouse Electric Corp., 1991) used a frequency of 5E-05 failures per forklift operation when a crew of two is performing the handling operations. A value of 1.5E-04 accidents per forklift operation, with a conditional probability of 2.5E-01 for drum rupture, leading to a breach frequency of 0.4E-04, was used in a probabilistic safety analysis of a LANL facility (Sasser, 1992). The LLMW systems analysis (EG&G, 1992c, 1993a) used a value of 1E-03 drum breaches per operation but included very minor breaches and spills. Finally, analysis of actual event data at the SRS resulted in a forklift drum drop probability of 5.0E-5 per operation and a drum piercing probability of 3.0E-5 per operation (WSRC, 1994).

On the basis of all of these studies, a probability of 1E-04 per operation for significant drum breaches consistent with the aforementioned estimates of source term parameters was used in the analysis herein. To apply this operational failure probability to storage area facilities, residency times in the interim storage area, which vary greatly, must be considered. Most areas are simply staging areas for treatment or disposal operations. Generally, for such staging areas, two handling operations would exist, one for receiving and one for removal. Thus, the expected annual frequency (f_{mb}) of a container breach for waste product x caused by a handling accident is

$$f_{mb} = 0.0002 \times n_x \ , \qquad \text{(F.2-3)}$$

where n_x is the number of waste containers of waste product x received annually. To convert this value to a throughput number, a conservative assumption was made that the complete inventory turns over each year. Then the expected annual frequency of significant mechanical breaches is given by

$$f_{mb} = 0.0002 \times N \ , \qquad \text{(F.2-4)}$$

where N is the capacity of the facility in number of drums.

The previous frequency estimate should envelop frequencies of breach of postprocessing storage containers that contain immobilized residues from treatment. With the exception of potential gas generation and pressure buildup, no significant breach mechanisms are present. For miscellaneous TRUW solids, the SAR for the RWMC (EG&G, 1993b) includes a facility frequency estimate of 2.1E-02 events per year for severe internal stresses, such as a hydrogen pressure buildup from radiolysis of cellulose material or other gas-generating mechanisms. Thus the operational estimate of Equation F.2-4 envelops this facility estimate.

The frequencies for container damage internal to a treatment facility would also be expected to be lower than those for lag storage because of the significantly lower inventory of drums and reduced drum vulnerability during handling. The estimate for metal-box drop and breach was 1E-02/yr for WRAP Module 2 (DOE, 1991c). A value of 3.8E-02/yr is estimated for the crane-drop scenario for the WRAP Module 1 facility (WHC, 1991a). For processing facilities, fewer drums and other packages are handled per year than would be the case for the range of potential operations of the lag storage areas (for example, consolidation of the contents of a number of waste pads onto a new pad). Furthermore, the operating conditions internal to a processing facility are superior to outside pads in terms of equipment reliability and working environment.

An approach similar to that discussed previously is used for estimating container breaches from operational events involving canisters of vitrified HLW. The glass product is noncombustible, and the stainless steel canister used as a container for the glass offers a high degree of protection from external incidents (for example, the HLW canisters are designed to be dropped from a height of 9 m [30 ft] without loss of integrity). Beyond 9 m (30 ft), the integrity of the canisters is uncertain (for example, the maximum height that a Hanford canister can drop in a storage facility is 13 m [42 ft]). Canisters are probably most vulnerable to damage during transfer from the onsite canister transporter into the vault tube (Braun et al., 1993). On the basis of this observation, the only accident analyzed for the glass storage facility is an operational event involving the crush-impact of a glass canister. Given that a simple drop of a canister (from a height less than 9 m [30 ft]) would not result in a breach, canister rupture would require the drop of a heavy structure (for example, a crane or concrete cover) on top of a canister during handling.

The estimated frequency for a canister breach for the Hanford glass storage facility, which would handle approximately 370 canisters, is 4E-03/yr (Braun et al., 1993). By assuming that the annual frequency of a canister breach depends on the number of canisters, which is taken to be equal to the annual rate of canister production, the frequency for an HLW breach (f_{HLW}) is

$$f_{HLW} = 0.004/370 = 0.00001/canister \quad . \tag{F.2-5}$$

Thus the frequency for canister break at SRS is approximately 4E-03/yr on the basis of an annual production rate of 410 canisters per year. The West Valley Demonstration Project (WVDP) will handle approximately 100 canisters per year, and the annual frequency for canister break is therefore 1E-03/yr. The preliminary design at Hanford assumes a production rate of 890 canisters per year, leading to a frequency of 9E-03/yr.

The frequencies for chemical spills involving HW or LLMW are derived by using site-specific inventories of individual representative chemicals, along with the previously identified assumptions on frequencies of breach per operation. Conditional probabilities of fire or explosion of chemically reactive or combustible chemicals are also developed. These discussions are included in the sections on HW and LLMW accident analyses.

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F.2.6.2 Storage or Staging Area Accidents

The major concern with storage and some staging facilities is the large inventory of waste in a centralized area and releases involving fires or explosions. The sections that follow summarize the accident types considered that would affect either dedicated storage areas or areas for staging waste prior to treatment. The discussion is generic in that it is not tied to a specific treatment process or waste type. The final determination of source term parameters for HW storage accidents is dicussed in the section addressing that waste type.. Both internally initiated accident sequences and external events were taken into account.

F.2.6.2.1 *Internally Initiated Fires*

Internally generated facility fires generally occur because of ignition of fuel sources, combustion of rubbish, or spontaneous combustion of the contents of a waste package. Combustible or flammable fuel sources include diesel fuel or gasoline for tractors, trucks, or other vehicles and natural gas or fuel supplies. Combustible rubbish fires generally result from poor housekeeping and are probably the principal cause of minor facility fires. Spontaneous combustion of the contents of a waste package has been reported (DOE, 1990a) but is considered unlikely.

Design and operational safeguards are in place to prevent propagation from a localized source (such as a single package or drum or a rubbish pile) to a much larger inventory. Packages for combustible materials are either steel drums, fire-resistant boxes, or fire-protected shipping containers. Moreover, sites are generally bound by the RCRA to segregate storage by waste form compatibility and RCRA category; therefore, combustibles are segregated. Finally, most facilities have fire detection and suppression capabilities from fire-watch or operator surveillance, automatic sprinkler systems, fire barriers, or onsite fire department response (or some combination of these types of protection). As a result, fires can be categorized as either local fires involving very limited inventories of wastes or, at the other end of the spectrum, as major facility fires induced by forces that provide a source of fuel (such as gasoline) and that also disable or overwhelm any available safeguards. Accidents affecting staging-area waste packages can generally be enveloped by those affecting storage areas because of the similarity of the primary containment (packaging) and are included herein.

Evaluation of Source Term Parameters. The MAR in all fire scenarios is limited to the waste exposed to the fire, which depends on the facility configuration and the detection of and response to the fires.

The DF is a strong function of the packaging and the physical form (and combustibility) of the MAR. Two categories of fires were considered: waste-container fires and facility fires. The former category was assumed to have a MAR equivalent to the contents of a single 208-L (55-gal) drum and to have a DF of 1E+00. The representative fire in a storage facility was assumed to encompass the spectrum of undetected or unsuppressed fires, and the entire facility's inventory of waste was assumed to constitute the MAR. A DF of 1E-01 was assumed as a generic value to account for segregation and separation of waste packages in the facility and for the nature of the waste packaging as described previously.

Evaluation of Frequencies. Reported fire-initiator frequencies for drum storage (DOE, 1990b; Salazar and Lane, 1992; EG&G, 1993b) for operationally related events range from 1E-03/yr to 2E-04/yr. The higher value is estimated for general miscellaneous combustibles. The lower value is also fairly typical of estimates for scenarios involving ignition of leaking fuel or natural gas. Because some references distinguish between operationally generated waste and the packaged waste being stored, the upper value is probably associated with poor housekeeping. For fire initiating in a waste package, frequencies on the order of 9.2E-04/yr have been reported for the RWMC (EG&G, 1993b). This range of values is inferred to apply to storage situations involving minimal intervention by operators. Fire frequencies associated with fuel from transport vehicles, cranes, and forklifts range from 3.3E-03/yr to 8.3E-04/yr for initiation (Davis and Satterwhite, 1989; EG&G, 1993b). Fires resulting from subsequent ignition upon violent breach of TRUW drums can be envisioned because of hydrogen buildup from alpha activity in contact with cellulose material (DOE, 1990a). Although frequencies for waste-package damage scenarios have been estimated, conditional probabilities for ignition and fire following package breach have not been reported, but would be higher for TRUW than for LLW and LLMW, for which hydrogen buildup is much less likely.

Because of the relative infrequency of a single-container fire and the much greater consequences of fully developed facility fires, only the latter were analyzed for source term development for the WM PEIS. The estimated annual frequency is 1E-4/yr for a fully developed facility fire in the absence of treatment process operations. (See also section on treatment facility fires.) This frequency is the product of a generic facility fire frequency of 1E-2/yr and a fire suppression system failure probability of 1E-2 (DOE, 1982). This value is consistent with existing documentation and is judged to be reasonable in light of the existing preventive and mitigative safeguards discussed previously.

F.2.6.2.2 *Internally Initiated Explosions*

Explosion scenarios for packaged wastes can be postulated for LLMW, TRUW, and HW. Most LLMW accident analyses focus on storage of miscellaneous organic liquid waste (for example, benzene at the SRS [WSRC, 1994]), where blankets of inert gas serve to preclude ignition and detonation. Most TRUW analyses focus on the accumulation of hydrogen or methane from radiolysis of organics, with subsequent ignition and detonation. Inadvertent chemical reactions are considered for HW but should be unlikely because waste sorting and segregation at the point of generation act to preclude combining reactive materials and oxidants. Storage activities are generally not climate controlled, but heating gas is a candidate source for explosion where some control is maintained. Postprocessing storage is less of a problem than pretreatment storage because of the greater stability of the final forms (for example, grout).

Damage to packages from an explosion is governed by projectile behavior and the location and configuration of the package. One type of array is a four-tier-high stack of two pallets, each holding a two-drum-high, tightly packed array of four drums (Salazar and Lane, 1992). Here, the number of drums that could be directly affected by projectile impact would be five, although the array could be toppled, or other ancillary damage (for example, to adjacent arrays) could be envisioned. A similar rationale applied to waste boxes would indicate two affected adjacent boxes.

Evaluation of Source Term Parameters. The MAR for an explosion would generally be limited to a single package because very little explosive energy is typically associated with currently generated wastes, and extrapolation of scenarios to include high-energy projectiles is difficult. The DF for explosions internal to a container would be 1E+00 (that is, the entire contents of the package are assumed to be affected). This damage is judged to conservatively envelop any projectile damage to nearby packages. For external explosions, projectile damage to a waste package is similar to puncture of a package; and a damage ratio of 2.5E-01 or 1E+00 would be expected, depending on whether the contents are solid or liquid.

Evaluation of Frequencies. The WRAP Module 1 at Hanford (WHC, 1991b) considered various potential explosions for CH TRUW and LLW operations and assigned a frequency range of 1E-06/yr to 1E-04/yr for a drum exploding because of hydrogen buildup during storage in the shipping and receiving area (after receipt). Presumably, the hydrogen resulted from radiolytic decomposition of H_2O or hydrocarbons, which is plausible for TRUW but unlikely for LLMW. A glove box (sorting area)

explosion frequency of 6.3E-05/yr was estimated for opening a RH TRUW drum containing a hydrogen-air mixture with failure to vent, failure to detect, and ignition.

Because of the relative infrequency of single-container explosions, and the lack of any known large-scale explosions, radiological source terms for explosions in storage and staging areas for other than hazardous waste were not judged sufficiently important to risk to justify source term development. Process explosions, however, were analyzed as discussed in the section on treatment facility accidents.

F.2.6.2.3 *External Event Accident Sequences*

External event challenges are important to the human health risk from radiological releases insofar as these challenges have the potential to create fires or explosions that can disperse and render airborne radioactive waste materials. As discussed in Section F.2.3.1, plausible external accident initiators leading to direct fire and explosion scenarios include impacts from military, general aviation, or commercial aircraft; impacts from large trucks carrying fuel or chemicals; and fuel or process chemical fires and explosions in nearby facilities or storage tanks. Natural phenomena such as earthquakes can cause natural gas, fuel, or process chemical fires and explosions in nearby facilities. The severity of such phenomena makes mitigation by onsite fire brigades very unlikely.

Event trees described by Mueller et al. (1995) are used to model the accidents caused by external events and to project the progression of the accidents through plausible generic sequences. The event tree methods are based on accepted probabilistic risk assessment methods and are consistent with methods prescribed by the NRC, the American Institute of Chemical Engineers (1989), and the DOE. Accident sequences are developed for aircraft impacts (small aircraft and large aircraft are considered separately) and seismic events. As discussed in Section F.2.3.1, the safety impacts of aircraft accidents envelop impacts for other man-made severe external challenges, and the damage and safety impacts from seismic events generally envelop effects from other natural phenomena. These accident initiators and the associated accident sequences are developed for the designs for the generic facilities described in section F.2.5. The results are covered in the chapters on specific waste types.

F.2.6.3 Treatment Facility Accidents

The major concern with treatment facilities is fire- or explosion-driven releases of process inventories that are often much more concentrated than the inventories of waste in current storage or in staging areas. This section primarily summarizes internal event-initiated treatment process accident types and discusses the associated source term and frequency data used for the analyses. However, external event sequences were also analyzed using event trees in Mueller et al. (1995) to structure and facilitate the evaluation. Results for both internal and external events are shown in the individual sections for each waste type.

F.2.6.3.1 *Treatment Process Incidents*

In general, the processes of the generic treatment facility described in Section F.2.5.1.3 entail minor hazards to the operating staff, including puncture wounds during waste sorting, minor contamination from glove failures, and minor spread of contamination from the events of treatment equipment pressurization, from spills, and from off-gas treatment confinement failures (corrosion, gasket failures, etc.). Such minor operational incidents in treatment have been folded into general handling accidents and, as a result, are not discussed further.

F.2.6.3.2 *Off-Gas System Failures*

Potential onsite and offsite effects may result from failure of the off-gas treatment system to perform as designed or from introduction, into the off-gas treatment, of species for which the treatment steps are ineffective (for example, noble gases, volatile radionuclides such as ^{3}H, or high-temperature conversion of dichlorodifluoromethane [HALON] to phosgene); but off-gas events tend to be minor because of the high gas sweep rate and the inertness of the off-gas constituents relative to the chemically reactive radionuclides and hazardous materials given off during facility fires and explosions. The onsite and offsite risks from such accidents are enveloped by potential facility fires or explosions that involve chemically reactive releases of nuclides and chemicals that have extended residence times in the body. Thus, these events are not considered further.

F.2.6.3.3 *Treatment Process Vessel Releases*

Aqueous processes to remove RCRA contaminants entail short term storage in tanks, transfer pumps, vessels, pipelines, and reaction vessels. Because most sites have some capability to reduce volume and to immobilize or to dispose of low-activity liquid wastes, long-term storage of these liquid wastes is limited to specific situations, such as the LLMW stored in tanks at Hanford. Nevertheless, rupture or failure of these tanks could arise from corrosion, internal stress, or external impact. More severe events can also be conceived, such as hoop stress failure from severe overpressurization (for example, vapor-space gas detonation from ignition of radiolytically generated hydrogen or benzene vapor), with subsequent fires or explosions; however, both frequencies and consequences for such severe events should be extremely low for all radioactive waste types except possibly HLW. Because tank storage of HLW is not included in the evaluation of the WM PEIS alternatives, such accidents are not addressed here.

On the basis of inventories of the various waste types and identified treatment technologies, wet-air oxidation of LLMW was selected as a potentially risk-dominant process with vessel breach the accident of concern. However, details of the process and related system descriptions were inadequately specified in the WM PEIS to allow detailed accident analyses. As a result, source terms for wet-air oxidation were analyzed by using MAR and facility containment parameters consistent with those used to analyze accidents involving incineration facilities (discussed subsequently). This approach allows an order of magnitude scoping of the risks of wet-air oxidation process accidents and provides a reasonable relative risk comparison with incineration accidents. The MAR was assumed to be the entire contents of the vessel (DF = 1E+00), which was assumed to hold 1 percent of the annual wet-air oxidation throughput at the site. The radiological composition at each site for each alternative was obtained from the WM database (Avci et al., 1994). An earthquake was the only plausible accident capable of rupturing the process vessel and at the same time defeating the facility containment integrity and filtration systems. For conservatism, the airborne release was assumed to be pressurized, with RARFs chosen accordingly.

F.2.6.3.4 *Treatment Facility Fires*

Two categories of fires at treatment facilities have been considered: (1) operation-specific fires developed from consideration of the characteristics of a particular treatment technology or the related

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process and facility characteristics, and (2) generic fires. Existing onsite safety documentation has been reviewed to develop the source terms and frequencies associated with plausible accident sequences for the first category, which includes fires in incinerator facilities. The CIF analysis (Du Pont, 1989) treats the fire initiator potential of the incinerator system as governed by the nature of the feedstocks and attributes the initiation of fire to (1) spontaneous combustion of solid waste in lag storage or (2) ignition of contaminated organic liquids in storage. The Waste Experimental Reduction Facility (WERF) (EG&G, 1993b) analysis considered a fire in the baghouse of the filtration system. Both analyses were used to define a reference scenario, as discussed subsequently.

Facility or facility operations characteristics other than those associated with the treatment process can clearly be correlated with the occurrence of fire. These characteristics include the presence of highly combustible materials (or materials that can undergo spontaneous combustion, such as dried tetraphenylborate salts), the existence of activities involving these materials (such as machining of pyrophorics), maintenance activities (such as welding) that involve fuel and ignition sources, and building characteristics such as the heating and electrical distribution systems (especially switchgear). The assumption is that these characteristics are reflected in the generic database used to establish the generic data on fire frequency discussed subsequently. Site-specific analyses include ignition of the contents of a breached drum and general room fires (Salazar and Lane, 1992). In general, existing LLW and TRUW safety analyses seem to focus less on facility fires than on other accidents; for example, analyses for the various Hanford WRAP modules mention but do not analyze fires. Engineering judgment, which is based, in part, on the information developed herein and largely presented in Appendix C of Mueller et al. (1995), has been used to assign reasonable source term and frequency parameters to generic facility fires.

Evaluation of Source Term Parameters. The representative incineration facility fire used to envelop radioactive releases is based largely on information for the WERF (EG&G, 1993b). The assumption that a fire starts in the baghouse of the filtration system and propagates to the HEPA filters is plausible because of the high temperatures of the material entering the baghouse. The fire causes the housing seals to fail on the baghouse and the filters, yielding a direct release of fly ash to the atmosphere. The total ash inventory accumulated in the baghouse and the HEPA filters is assumed to constitute the MAR. It has been assumed that the ash fed to the baghouse during the fire, if the facility has not shutdown, is a small fraction of the ash accumulated in the baghouse, and it is therefore neglected in the calculations. The MAR was estimated by averaging the fractions of the total facility ash inventories in the CIF and the Process Experimental Pilot Plant (PREPP) actually present in the baghouse and

HEPA filters, a value of roughly 3E-02 (Du Pont, 1989). All of the baghouse and HEPA filter ash was assumed to be affected by the fire, resulting in a DF of 1E+00. Any subsequent explosions of accumulated waste ready to be incinerated were judged to be enveloped by the dispersion of ash. A more detailed description of the external events analyses can be found in the report by Mueller et al. (1995).

The representative incineration facility fire for HW used to envelop hazardous releases assumes that the fire engulfs the feedstock. For further information, refer to the HW analysis.

Evaluation of Frequencies. Fire frequencies for production operations are based on occurrences in the SRS data bank for the operations in the SRS 200 Area and on other industrial experience. The frequency of spontaneous ignition of accumulated combustibles (poor housekeeping) is 5E-01/yr if (1) pyrophorics or (2) nitric acid and cellulose are available. The CIF analysis (Du Pont, 1989) assigned a value of 2.6E-02/yr for fire initiation in the lag storage area for cardboard boxes, on the basis of general experience with spontaneous combustion for F and H Canyon operations. The SAR for the CIF also addressed the possibility of a fire involving waste organic feedstock (5E-03 per tank per year, with three tanks). Maintenance activities, depending on the circumstances (confined space welding, use of greenhouses, etc.), initiate fires with a frequency of 3E-01/yr to 2E-01/yr. Fires from electrical shorts have similar frequencies. The expected frequency for a process-related fire in a canyon facility has been estimated to be 1.5E-02/yr on the basis of experience in the SRS's F and H Canyons (WSRC, 1994).

Analysis of actual event data at the SRS indicates a failure probability for manual fire suppression of 1E-01 to 5E-01 per demand, assuming the fire is detected (Benhardt and Held, 1994). Most SARs use a reasonably conservative value of 1E-02 per demand for failure of automatic fire suppression systems on the basis of the DOE study (DOE, 1982). More recent analyses of Hazard Category 2 facilities indicate a greater reliability for wet pipe sprinkler systems. Typical site-specific values range from 5E-02 to 1E-03 per demand for a fire department to fail to respond. Also, the SRS data indicate a probability range of 3E-02 to 3E-01 for the fire department to successfully put out the fire. Because this analysis presumes either automatic or manual fire detection and notification, either or both are required for any credit to be taken.

The EIS for the WIPP (DOE, 1990a) applies a frequency of 1E-03/yr for a fully developed fire in an operating area, as derived from the RWMC documentation. The previously cited study by the Electric

Power Research Institute (EPRI, 1979) estimates 1E-02/yr for a fully developed fire (on the basis of a generalized fire initiator of 1E-01/yr), and general estimates of fire initiator frequencies (for TRUW processing and handling activities) for the RFETS range from 5E-02/yr to 5E-01/yr on the basis of facility-specific experience (for example, Building 910 [EG&G, 1992a]). The RWMC analyses (EG&G, 1993b) are predominantly focused on fires initiated by helicopter crashes (in various locations), typically with a frequency of 1.2E-05/yr to 5.4E-05/yr. Other sites are more concerned with external challenges from aircraft crashes and earthquakes. Aircraft fuel, ruptures of natural gas pipelines, and spilled organic liquids in storage facilities constitute the combustible or ignitable source for these challenges.

The estimated frequency for a fully developed facility fire used herein is 1E-03, consistent with WIPP estimates. This estimate includes a generic fire frequency of 1E-01/yr and a fire suppression system failure probability of 1E-02. In light of safeguards associated with hazard category 2 facilities, this estimate is judged to be conservative. For the HW feedstock fire, refer to the HW analysis section.

F.2.6.3.5 *Treatment Facility Incinerator Explosions*

Except for incineration and wet-air oxidation (of mainly aqueous wastes, with less severe consequences), no significant explosion initiators were identified for processing. Failure of a wet-oxidation unit would result in a pressurized spray release. Nitrated organic reactions at high temperatures in evaporators and driers were discounted in the SARs for RFETS Building 910 and Building 374 (EG&G, 1992a,b) because (1) alkaline solutions do not react significantly, (2) heavy metals are absent, and (3) processes are at low pressure. In general, the accident literature for evaporation focuses primarily on accidents involving loss of filtration; however, unlike many processing activities, incineration has a potential for accumulations and leaks of combustible gas, with a possibility for explosions.

Evaluation of Source Term Parameters. The assumption is that the explosion (which could potentially occur because of the existence of fuel, oxygen, and high temperatures) takes place inside the rotary kiln incinerator. The MAR was derived by averaging the ash inventory at the CIF and PREPP in the kiln incinerator and was determined to be 12 percent of the total ash inventory existing in the facility. All of the waste present in the rotary kiln incinerator was conservatively assumed to be affected by the explosion, for a DF of 1E+00.

Evaluation of Frequencies. The safety analysis for the CIF, which is designed to accommodate LLW but includes various RCRA wastes as candidate feedstocks, estimates an annual frequency of 1.5E-02/yr for explosions in the rotary kiln assembly and in the secondary combustion chamber. Because it envelops the other estimates, the CIF estimated frequency of 1.5E-02/yr is used herein. A frequency of 2.9E-04/yr for an explosion during RWMC processing activities was estimated (no unit operation is specified), with a frequency for a facility room fuel-air explosion estimated at 2.0E-04/yr (previously reported values were as low as 5E-07/yr). A more refined and detailed analysis estimated that conditions conducive to an explosive event exceeding the 100-kilopascal (kPa) (15 pounds per square inch gauge [psig]) capability of the vessels could occur at a frequency approaching 3E-02/yr. Such overpressures could potentially rupture the vessels and release the contents. Various INEL studies cite an explosion frequency of 1E-04/yr derived primarily from earlier analyses to support operations of the RWMC/Solid Waste Experimental Pilot Plant (SWEPP) with TRUW solid feedstock (EG&G, 1993b).

The posttreatment stored waste may be presumed to be more stable (depending on the method of immobilization) and more robustly packaged. The only qualitatively defined scenario entails a propane gas leak with ignition. The SAR for RFETS Building 910 assigned a conservative value of 4.4E-02/yr for a heating gas line rupture and ignition to impact postprocessing material stored in the processing facility. Because the source term for this accident is much smaller than that for the rotary kiln explosion, this sequence was not developed further.

F.2.6.4 Summary of Data Used

A summary of the key generic source term and frequency parameters discussed in the preceding sections is presented in Table F.2-5. Although the values actually applied for the accidents for the individual waste types are summarized in the chapters on specific-waste-type accident analysis, these values are largely based on this table. The MAR units of volume were converted to Ci for each waste type and DOE site with the information provided in the PEIS waste characterization database. Although the total Ci value is given in the table, the activity was distributed into the corresponding radionuclides in the source term files used for consequence calculations.

Table F.2-5. Frequency and Source Term Parameters for General Handling and Internal Facility Accidents

Event	Reported Annual Frequencies		WM PEIS Frequency Estimate per Year	Reported or Representative Source Term Parameters		
	Low	High		MAR	MAR Units	DF
General Handling Accidents						
Packaged Wastes						
Crane drop with impact and breach	8E-02	1.2E-01	-[a]	1E+00	Package[b]	2.5E-01 or 1.0E+00[c]
Forklift puncture with impact, breach, and spill	-	7.5E-02	-	2E+00	Package	1E-01 or 1.0E+00[c]
Internal overpressurization and breach	-	2.1E-02	-	1E+00	Package	-
Toppled stacked array	-	7.5E-02	-	4E+00	Drum	2.5E-01 or 1.0E+00[c]
Representative breach and rupture	-	-	2.5E-04[d]	1E+00	Drum	2.5E-01 or 1.0E+00[c]
Fires in Storageor Staging Areas						
Spontaneous-combustion fire	2.6E-02	5E-01	-[f]	1E+00	Drum	1E+00
Small fuel or chemical fire	8.3E-04	3.3E-03	-[f]	2E+00	Drum	1E+00
Facility fire	2E-04	1E-03	-[f]	g	Drum	1E+00
Local manual-suppression failure	1E-01/d	5E-01	-	-	-	-
Automatic-suppression failure	-	1E-02/d	-	-		-
Fire brigade response failure	3E-02/d	3E-01/d	-	-		-
Representative facility fire without mitigation	-	-	1E-04	g	Drum	1E-01
Explosions in Storage or Staging Areas						
Packaged Waste (LLMW and TRUW Only)						
Spontaneous combustion or explosion	1.0E-06	1.0E-04	-	1E+00	Drum	1E+00
Representative explosion	-	-	-[f]	-	-	-
Fires in Treatment Facilities						
Facility fire						
Local manual-suppression failure	1E-01/d	5E-01/d	-	-	-	-
Automatic-suppression failure	-	1E-02/d	-	-	-	-
Fire brigade response failure	3E-02/d	3E-01/d	-	-	-	-
Representative facility fire without mitigation	-	-	1E-03	1E+00	Baghouse and HEPA ash inventory	1E+00

Table F.2–5. Frequency and Source Term Parameters for General Handling and Internal Facility Accidents—Continued

Event	Reported Annual Frequencies		WM PEIS Frequency Estimate per Year	Reported or Representative Source Term Parameters		
	Low	High		MAR	MAR Units	DF
Explosions in Treatment Facilities						
Spontaneous combustion or explosion	1E-04	1.5E-02	-	1E+00	Incinerator kiln ash inventory	1E+00
Representative explosion	-	-	1.5E-02	1E+00	Incinerator kiln ash inventory	1E+00

[a] Not available.
[b] A Type A 208-L (55-gal) plastic-lined carbon steel drum was chosen as the representative waste package for MAR calculations in determining source terms for all packaged waste breach or rupture events.
[c] Waste packages containing liquids were assigned a DF of 1.0E+00.
[d] Per operation
[e] Because of the focus of the WM PEIS alternatives and the low overall risk relative to drum or canister storage accidents in the WM PEIS program, source term analyses were not performed for tank storage.
[f] Because of the combined relative infrequency and low health impact of individual container fires and explosions, only facility fires were analyzed in the WM PEIS.
[g] Total number of waste drums in facility.
[h] Per demand.

F.2.7 Selection and Calculation of Final Source Terms

Preliminary combination of the source term information discussed previously with selected so called unit risk factors (actually unit dose conversion factor) was performed to develop preliminary screening estimates of the impacts of the accident sequences to determine the risk-dominant scenarios. Unit risk factors were developed to estimate the health effects on the exposed populations from releases of unit amounts of radionuclides or hazardous chemicals (see WM PEIS Appendix D). This involved (1) the development of or integration of existing information on the site-, facility-, and treatment-specific demographics to characterize the workforce and general population potentially exposed to hazardous material and (2) the development of the meteorologic and release dynamics and characterization data necessary for calculating the transport of radioactive or toxicological plumes to the exposed population. Final source terms for the scenarios most important to public risk were then developed on the basis of the importance to risk to the maximally exposed individual (MEI) at the site boundary.

The calculation of the source terms merged the frequencies and source term parameters for the accident sequences with the inventory characterization for the MAR. The computational framework and interaction of the code packages are illustrated in Figure F.2–7. Preliminary results of the operational and external event accident sequences described previously were screened for each waste type for the

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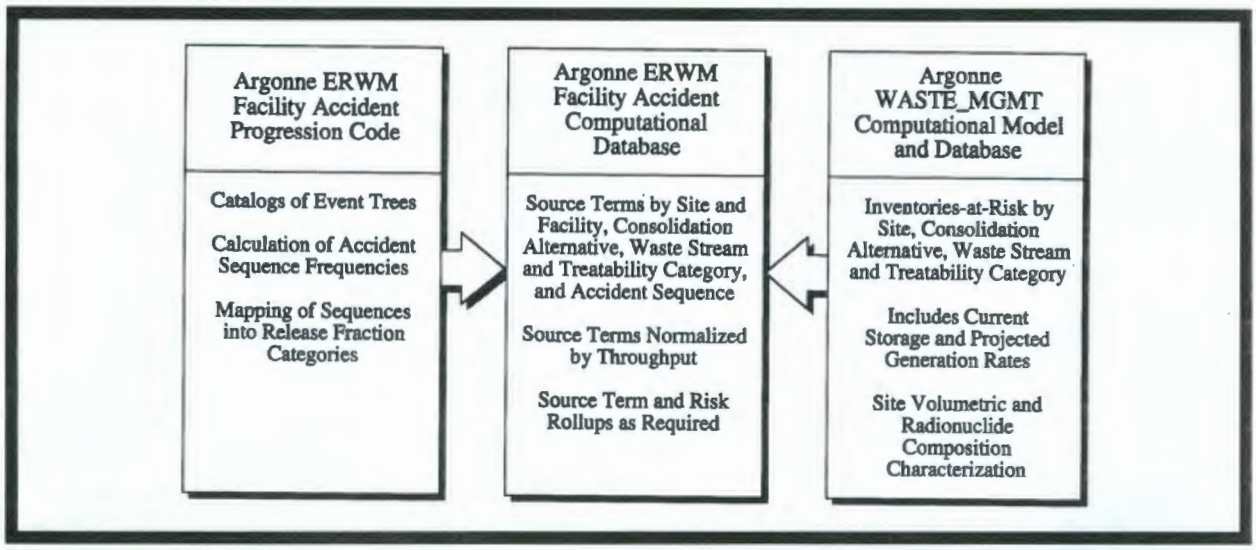

Figure F.2–7. Computational Framework for Facility Accident Analysis Source Terms. (ERWM = environmental restoration and waste management)

sites defined in the various alternatives for WM. Ranking of the accident sequences for risk dominance at each site was performed by using the frequency-weighted dose to the MEI as the screening criterion. Source terms were also selected from risk-dominant sequences in the following annual frequency categories: greater than 1E-02, between 1E-02 and 1E-04, between 1E-04 and 1E-06, and less than 1E-06. The selected source terms were then used to perform the health effects calculations for radiological and chemical releases from facility accidents. The complete set of sequences, with classification of their frequency categories, is shown in the chapters describing the results for each waste type. A representative list of sequences is presented in Table F.2–6. The final calculation of the health effects for both general and occupational workforce populations by using the source terms described herein is reported in WM PEIS Appendix D.

F.2.8 UNCERTAINTY IN FACILITY ACCIDENT ANALYSIS

Considerable uncertainties exist in various aspects of the facility accident analysis. The uncertainties range from issues pertaining to completeness of the analysis to numerical uncertainties in the parameters used in estimating the accident sequence frequency and the airborne release source terms.

Uncertainties in the representativeness and completeness of the accident analysis arise from inherent limitations of the accident sequence modeling and the incomplete knowledge of the facilities and operations involved. Representativeness was addressed by reviewing existing safety analysis

Table F.2-6. Representative Accidents Analyzed for Source Term Development

Type of Facility and Accident	Frequency	MAR × DF	Notes
Operational Handling			
Drum breach	2.0E-04/drum/yr	25% of drum (100% for liquid waste)	
Storage or Staging Area[a]			
Facility fire	1.0E-4/yr	10% of combustible drums in facility	Not applied to drums with vitrified, solidified, or otherwise highly stable waste or to noncombustible liquid waste
External Events			
Small- or large-aircraft impact	Site, aircraft, and accident sequence specific	Aircraft and accident sequence specific	Event tree sequences for both small and large aircraft screened on risk to identify single sequence
Earthquake[b] or tornado	Site[c] and accident sequence specific	Accident sequence specific	Event tree sequences screened on risk to identify single sequence
Treatment Facility[d]			
Operational Events			
Facility fire	1.0E-3/yr	Ash in baghouse and HEPA filters (3% of facility waste inventory or 0.03% of incinerable throughput)	Not for HW stream
Facility explosion	1.5E-2/yr	Ash in kiln (12% of facility waste inventory or 0.12% of incinerable throughput)	Not for HW stream
External Events			
Small- or large-aircraft impact	Site, aircraft, and accident sequence specific	Aircraft and accident sequence specific	Event tree sequences for both small and large aircraft screened on risk to identify single sequence
Earthquake	Accident sequence specific	Accident sequence specific	Event tree sequences screened on risk to identify single sequence

[a] Used for screening only.
[b] Earthquake used to upper-bound consequences of tornado.
[c] Frequency was assigned as the larger of those for a 0.15-g earthquake or a 113-kilometer per hour (km/h) (70-miles [mi]/h) wind.
[d] Applied only to incinerators at each DOE site. Vitrification accidents were screened out for LLW, and wet-air oxidation accidents were screened out for LLMW.

documentation and selecting accidents that were similar to or which bounded those found in the literature for the relevant operations, processes, and facilities. The issue of completeness was addressed by selecting surrogate accidents representative of classes of accidents and bounding the product of the frequency and the severity of the surrogates so that the risk from each class of accidents was enveloped.

The numerical estimates of the frequency of the different accident sequences analyzed are also uncertain. There exist uncertainties in both the frequency of the initiating events and in the conditional

probabilities of the accident progression path. The numerical estimates were generally conservatively obtained using accepted DOE or NRC safety guidance or site-specific safety documentation. Event trees were used to help organize the information, structure the sequences, and automate the calculations. Uncertainties in the frequencies of the sequences are expected to range from factors of from 3 to 10 for anticipated accident sequences (i.e., those with annual frequencies greater than 1E-02 per year) to from 2 to 3 orders of magnitude for accident sequences with frequencies near or less than 1E-05 such as those initiated by beyond design basis earthquakes.

The uncertainties in the source term calculations affect both the radiological and the chemical releases. The radiological source terms were calculated as the product of four contributing factors, namely MAR, DF, RARF, and LPF, all of which are affected by uncertainties. Uncertainties in the MAR and DF arise from lack of precise knowledge of waste stream inventory amounts, physical characteristics, radiological profiles, and operational and containment configurations of the treatment and storage of waste streams under potential accident environments. Estimates of the current inventory radioactivity contents (i.e., reflecting both amount and composition) are probably uncertain by factors of from 2 to 100, depending on the type of waste, where it was generated, and its current disposition. No conservatisms were assumed in developing the MAR. Damage fractions were chosen using generally conservative assumptions based on existing safety guidance and general knowledge of the physical characteristics of the MAR and the likely configurations and containment properties of the relevant storage and treatment facilities.

The RARF was conservatively adapted to the waste streams subjected to the dominant accident stresses encountered during the postulated sequences by assigning high or bounding values from the RARFs compiled in DOE-HDBK-3010-95 (DOE, 1994). The uncertainties caused by imprecise knowledge of accident stresses and imprecise extrapolation of experimental values, which themselves are uncertain, suggest uncertainty ranges from factors of 3 to 10 for high RARF values (say greater than 1E-02) to orders of magnitude for RARF values of less than 1E-04. Uncertainties in the physical compositions and containment configurations of the MAR suggest an additional order of magnitude in the RARF uncertainty.

The LPF uncertainties for sequences with full or partial filtration exist due to incomplete knowledge of leak paths and filtration efficiency during accident conditions. For sequences in which the containment structure is damaged, a LPF of unity is conservatively assumed.

The chemical release source term uncertainties in the MAR and DF parallel those for the radiological release source terms. Uncertainties due to the completeness of the HW database, which was developed from actual shipping manifests, are expected to be small, roughly a factor of two. For the hazardous component of mixed waste the chemical breakdown was more generic and was not available on a drum by drum basis as it was for HW, suggesting an order of magnitude uncertainty. Also, only a small number of accident release types were identified due to the generic nature of the chemical profile available for those mixed waste types. The uncertainty there is expected to add another order of magnitude. Uncertainties in the estimated chemical source terms are expected to have a variability of about one order of magnitude because chemical reactions can take place in different ways depending upon temperatures, the presence of catalysts, and the precise chemical concentrations of constituents, parameters for which there is very limited information only.

Recognizing that the uncertainties in the various source term factors are often interdependent, the uncertainty in source term estimates covers several orders of magnitude. Reasonable predictions of the distribution of source terms can not be quantitatively established without a much greater level of knowledge of the waste stream inventories, the future generation of wastes within each category, and the actual characterization of the operations, processes, facility configurations, operating and safety procedures invoked. Developing this level of knowledge is beyond the scope of the WM PEIS.

Although the absolute values of the source term estimates range in uncertainty to several orders of magnitude, the comparisons among the source terms are much less uncertain. Considerable effort was expended to assure that the accident analysis approach and underlying assumptions were consistently applied for all waste streams, types of accidents considered, and operations, processes and facilities evaluated. Thus the relative health and risk impacts, to the extent that they depend on relative source terms, that are ultimately derived from and calculated for different facility accident sequences are judged to provide useful information in discriminating among strategic alternatives.

F.3 High-Level Waste

F.3.1 ALTERNATIVES AND SITES ANALYZED

Management of HLW follows six implementation phases: current storage, retrieval, pretreatment, treatment, interim canister storage, and geologic repository disposal. Current storage, retrieval, pretreatment, treatment, and geologic repository disposal are outside the scope of the WM PEIS; and accidents during these implementation phases are not considered. The required WM facilities include expanded interim storage facilities under the various alternatives at Hanford, SRS, and WVDP.

Canisters of vitrified HLW from Hanford, SRS, and WVDP are to be placed in an interim onsite storage facility awaiting transport to a geologic repository. Comparison of the interim storage facilities at the three sites is given in Table F.3–1. Canisters produced at WVDP will be placed in storage racks that hold four canisters each and then will be transported in these racks to the onsite Waste Canister Storage Facility (WCSF). The immobilized HLW will be temporarily stored in a previously decontaminated and refurnished process cell known as the Chemical Process Cell (CPC), which has been modified for HLW interim storage. The racks will be stored on two levels to provide a storage area for failed equipment. The storage area has a capacity for 344 canisters and will be equipped with two coolers to remove the decay heat.

The interim canister storage facility at SRS is designed to hold canisters in vertically sealed cavities within a concrete structure forming the storage vault (that is, a concrete modular vault). The Glass Waste Storage Building (GWSB) at SRS will be an air-cooled dry storage vault. It consists of rows of tubes or vaults placed below grade into which the canisters are lowered. No stacking of canisters occurs within the storage tubes. Concrete plugs provide a cover for the tubes. Storage capacity is currently provided for 2,286 canisters, the output from approximately five years of vitrification operations at the Defense Waste Processing Facility (DWPF). The storage capacity of the existing facility was predicated on the assumption that a geologic repository would be available by the time when 1992 fresh waste would be processed. Additional storage capacity for 2,286 HLW canisters are required to assure interim storage of the total 4,572 canisters at SRS.

Table F.3-1. Interim Storage Facilities for HLW Canisters

Variable	WVDP	SRS	Hanford
Facility name	WCSF	GWSB	TBD[a]
Storage capacity (HLW canisters)	344	2,565[b]	15,000
Storage method	Process cell	Modular concrete vault	Modular concrete vault
Footprint (m^2)	190	4,343	12,200
Vault volume (m^3)	2,490	63,404	141,000
Cooling method	Air cooler	Exhaust fans	Natural convection

[a] Conceptual facility under design.
[b] Additional storage capacity of 2,286 canisters will also be required.

The previous design for the Hanford Waste Vitrification Plant (HWVP), was estimated to produce about 2,000 canisters of glass from high-activity waste from the Hanford double-shell tanks (DSTs). The number of glass canisters from single-shell tank wastes depends on the pretreatment process to be selected, with a maximum of 60,000 canisters having been projected for minimal pretreatment (U.S. General Accounting Office, 1993). This analysis assumes that a total estimated 15,000 canisters will be produced from all the HLW at Hanford. The vitrified waste canisters are to be placed in interim storage onsite. This storage is similar to storage at SRS, except that three canisters are stacked per storage tube and a thermosiphon ventilation system would be used to remove decay heat in the Hanford design. As currently designed, the conceptual facility at Hanford would be able to store 15,000 canisters containing vitrified HLW. Detailed descriptions of HLW treatment processes and facilities can be found in the report by Folga et al. (1995).

The HLW alternatives in the WM PEIS are shown in Table F.3–2. The decentralized alternative would provide onsite interim storage for all treated HLW awaiting shipment to a geologic repository for permanent disposal. The regional consolidation alternatives call for the vitrified-HLW canisters produced at one site (or sites) to be transported for interim storage at another site. Centralization at one site (Hanford) is also considered.

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Table F.3–2. Programmatic Alternatives for HLW

No Action Alternative

- Store HLW canisters at Hanford, SRS, INEL, and WVDP in existing and approved storage facilities;
- Continue current treatment approaches at each site.
- Continue interim storage of liquid and calcine HLW at INEL; and
- Continue activities necessary for ultimate disposal of HLW in a geologic repository.

Decentralized Alternative

- Continue storage of HLW at Hanford, SRS, INEL, and WVDP;
- Continue current treatment approaches at each site;
- Continue interim storage of stabilized (vitrified or glass-ceramic) HLW at each site; and
- Continue activities necessary for ultimate disposal of HLW in a geologic repository.

Regionalized 1 Alternative

- Same as Decentralized Alternative, except provide interim storage facilities at SRS for WVDP vitrified HLW canisters.

Regionalized 2 Alternative

- Same as Decentralized Alternative, except provide interim storage facilities at Hanford for WVDP vitrified HLW canisters.

Centralized Alternative

- Same as Regionalized 1, except provide interim storage facilities at Hanford for WVDP, INEL, and SRS HLW canisters.

F.3.2 Risk-Dominant Accidents and Modeling Assumptions

F.3.2.1 Selection of Accidents

Accidents with the potential to produce significant offsite consequences were identified by using available safety documentation. Although HLW contains various hazardous components, the primary risk is from radiological hazards. Because of the stable nature of vitrified waste, chemical releases do not occur in interim storage, the only WM phase of relevance to the WM PEIS.

Nuclear criticality was discounted due to the low concentration of fissionable material in the canister and due to the absence of a mechanism of accumulating a critical mass. This assumption was supported by safety documentation. The effective multiplication factor for criticality in an interim storage facility is required by 10 CFR 60.131(b)(7) (1993) to be at least 5 percent below unity. Reported values for SRS canisters show a large margin of subcriticality (McDonell and Jantzen, 1986). Because the inventories of fissionable radionuclides at Hanford and WVDP are lower than at SRS, an even greater margin would be expected.

Radiological releases from severe fires and explosions were considered first. DOE Order 5480.7A (DOE 1993g) establishes requirements for an improved level of risk for fire protection for all facilities for which either loss of value or risk to health and safety would be of concern. The SARs for the various HLW interim storage facilities (Herborn and Smith, 1990; WSRC, 1990; West Valley Nuclear Services Co., Inc., 1994) do not consider the risk of fire within an interim storage facility, generally because no significant accumulation of combustibles occurs in the vicinity to support significant fire propagation. Thus, a major destructive fire was judged to be unimportant to risk. Similarly, because a large source of combustible material would not be available for ignition or chemical reaction (or both), the possibility of a catastrophic operational explosion was discounted. An aircraft crash with a resulting aviation fuel fire was also discounted because it would have a frequency of less than 1E-06/yr and limited radiological consequences, given the containment of the encapsulated radioactive materials (Mishima et al., 1986).

Natural phenomena were also considered, with the limiting accident being an earthquake. Braun et al. (1993) estimated an annual frequency of 3.37E-08/yr for an earthquake-induced canister drop with subsequent airborne release for interim storage at Hanford (this scenario assumed full filtration; loss of filtration would result in an even lower frequency estimate). In general, natural phenomena-induced events, such as tornadoes and earthquakes, were discounted as important contributors to the overall risk of HLW interim storage operations (Braun et al., 1993) due to the high integrity of the HLW canisters, as well as the low probability of occurrence.

Review of the available safety documentation (DOE, 1982; Idaho Operations Office, 1982; Machida et al., 1989; Mishima et al., 1986; WSRC, 1990) suggests that the risk-dominant accident during interim glass canister storage is the breaching of an immobilized canister during handling operations, including a canister drop from the shielded canister transporter (SCT) into the vault tube during transfer, and canister damage during transfer because of movement of the SCT cask relative to the vault

tube opening (Braun et al., 1993). A rupture could also occur from a cell cover dropping on an encapsulated canister. (Because a cell cover weighs approximately 27,216 kilograms [kg] [30 short tons (tons)], canister rupture is expected following a direct hit.) The initiating event is attributable to operator error in handling or to handling equipment failure (NRC, 1988). Particulates would then be generated that are small enough to be suspended and hence could be exhausted to the atmosphere. The energetics of the accident would not be expected to severely degrade the facility filtration. At the time of rupture, each canister is assumed to be full.

The estimated frequency for a HLW canister drop with subsequent release at the Hanford glass storage facility, which would handle approximately 370 canisters per year, is 4E-03/yr (Braun et al., 1993). The frequency of a canister breach depends on the number of handling operations, which is taken to be equal to the annual canister production rate:

$$\textit{frequency}\ (yr^{-1}) = (0.004/yr) \times \textit{canister production rate}/370 \qquad \text{(F.3-1)}$$

This analysis assumes a canister loading rate of 790 canisters per year for Hanford; therefore the initiating frequency for a canister drop at Hanford is estimated to be about 8E-03/yr. Given the previous information, the initiating frequency for a canister drop accident at SRS is estimated to be 4E-03/yr, on the basis of an annual production rate of 410 canisters per year. (The frequency of a canister rupture at SRS is estimated [WSRC, 1990] to be 2E-03/yr; the value used in this analysis can therefore be considered to be conservative.) The WVDP facility will only handle approximately 100 canisters per year, and the annual frequency is therefore reduced to 1E-03/yr.

F.3.2.2 Source Term Modeling Assumptions

Site-specific compositions were assumed for the MAR (taken to be the contents of one canister). A full canister of glass generally contains between 1,650 and 1,900 kg (3,638–4,189 lb) of glass (see Table F.3-3). This analysis also assumes that the mechanical impact from the canister drop accident results in fracturing the vitrified HLW and breaking the canister. The glass particles are released from the damaged canister (DF of unity) and are dispersed into the vault. The majority of the glass fragments are too heavy to remain airborne, with a fraction (1.5E-04) of the glass lying within the respirable range (< 10 μm). The RARF for vitrified glass that has been subjected to a crush/impact accident stress is shown in Table F.3-4 as a function of filtration.

Table F.3–3. Dimensions, Weights, and Radioactivity of HLW Canisters

Variable	WVDP	SRS	Hanford
Outer diameter (cm)	61	61	61
Overall height (cm)	300	300	300
Material of construction	SS; 304 L[a]	SS; 304 L	SS; 304 L
Nominal wall thickness (cm)	0.34	0.95	0.95
Weight (kg)			
Canister	252	500	500
Glass or ceramic	1,900	1,682	1,650
Total	2,152	2,182	2,150
Radioactivity per canister (Ci)[b] (January 1990)	104,300	234,400	137,000
Decay heat per canister (W)[c] (January 1990)	311	709	389

[a] SS = single shell.
[b] Ci = curie(s).
[c] W = watt(s).

The analysis of emissions from the Interim Fuel Storage Facility (IFSF) at assumes that all emissions are ground releases because the release point is not greater than 2.5 times the associated building height (Pinkston, 1993). Because stack locations and heights cannot be defined until a conceptual design has been completed, ground releases were assumed here with both full filtration and loss of filtration. While these two sequences are to be applied for public risk estimation, worker risk is based on unfiltered releases.

F.3.3 Results

Preliminary results of the accident sequences described previously were reviewed for importance to risk to the public by using the frequency-weighted dose to the MEI and then were grouped into the four annual frequency categories (Table F.2–2). Representative source terms for the important sequences were then selected as the bases for calculations of human health effects. The source term parameters and frequency groups for HLW accidents for all WM PEIS alternatives are shown in Table F.3–5. Detailed radionuclide releases are provided in the report by Mueller et al. (1995).

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Table F.3–4. RARF as a Function of Filtration for HLW Storage Facility Accidents[a]

Variable	Loss of Filtration	Partial Filtration	Full Filtration
RARF	1.5E-04	1.5E-07	3E-10

[a] Double banks of HEPA filtration are assumed; efficiency of first bank is 99.9%; efficiency of second bank is 99.8%.

Table F.3–5. Frequencies and Source Term Parameters for WM HLW Accidents Analyzed

			Frequency Bin (per year)				Source Term Parameters			
WM PEIS Alternative	Site	Accident	>1E-2	1E-4 to 1E-2	1E-6 to 1E-4	<1E-6	VMAR[a] (m^3)	MAR (Ci)	DF	Total Release (Ci)
All	Hanford	Glass canister crush, fully filtered release	-[b]	X	-	-	6.2E-01	1.4E+05	1.0E+00	4.1E-05
All	Hanford	Glass canister crush, unfiltered release	-	-	-	X	6.2E-01	1.4E+05	1.0E+00	2.1E+01
All	SRS	Glass canister crush, fully filtered release	-	X	-	-	6.2E-01	2.3E+05	1.0E+00	7.0E-05
All	SRS	Glass canister crush, unfiltered release	-	-	-	X	6.2E-01	2.3E+05	1.0E+00	3.51E+01
All	WVDP	Glass canister crush, fully filtered release	-	X	-	-	6.2E-01	1.1E+05	1.0E+00	3.3E-05
All	WVDP	Glass canister crush, unfiltered release	-	-	-	X	6.2E-01	1.1E+05	1.0E+00	1.7E+01

[a] VMAR = volume of MAR.
[b] Not applicable.

F.4 Transuranic Waste

Following the generation of preliminary source terms, a number of new or previously unavailable accident analyses addressing storage facility accidents have been obtained that were performed in support of recently published DOE Safety Analysis Reports (SAR's) and EIS's. Another new document of particular relevance that has just been published is the new DOE Standard (DOE-HDBK-3010-94, December 94) on respirable airborne release fractions, (RARF's), which provides the latest RARF values published by DOE for use in accident analysis. A RARF is defined as the fraction of material exposed to accident stresses that become airborne as a result of the accident. These latest values supersede the RARF values used in the screening studies cited above. At the time of this writing, these reports were being reviewed to provide additional insights into the development of the postulated WM PEIS facility accidents and the development of the final values of the associated source terms. The analyses for accidents that will be published in the final draft of the WM PEIS will reflect the information in these reports.

Accidents for current storage were not analyzed because the results will not help to discriminate among alternatives. This results from the underlying assumption used in the PEIS analyses that all sites will accumulate or at least not reduce these waste inventories for roughly ten years at which time complex-wide treatment will begin. Thus all sites will achieve their maximum inventories (leading to maximum potential releases), independent of alternative. However, because recent DOE safety or NEPA information on storage facility accidents provides guidance on the potential risk impacts applicable to storage, this information is discussed herewith.

Current SAR's and DOE site EIS's predict consequences for a range of selected waste storage accidents of varying frequency. A brief summary of some of these accidents, assumptions used by the sites in preparing the analyses, and release or health effects-related results are shown in Table F.4-1 and discussed below.

Table F.4–1 includes accident results from recent analyses such as the LANL *Preliminary Safety Analysis Report for the Retrieval of Transuranic Waste* (PSAR) (Benchmark, 1994) and the INEL SAR for the Waste Storage Facility (EG&G, 1994b). The LANL PSAR analyzed three credible accidents, including drum spill due to failure during handling, puncture of a crate by a forklift, and breaching of multiple drums in storage due to earthquake-caused toppling from storage arrays. In addition, LANL analyzed one beyond-design-basis accident defined as a single drum fire in the retrieval dome. LANL estimates that only about 0.4 percent of the drums contain a potential source of hydrogen that could

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Table F.4–1 Representative Accidents and Source Term Parameters from Recent DOE Safety Analysis Documents Relevant to TRUW Storage

Safety Document	Scenario	DF[a]	ARF or RARF[b]	Release	Consequence
LANL PSAR for Retrieval of TRUW (Benchmark, 1994)	1. Drum spill at retrieval dome	5.0E-01	1.0E-03 to 5.0E-05	8.7E-04 PE-Ci[c]	1.7E-02 rem (MEI)[d]
	2. Forklift puncture of crate in storage dome (4 drums)	5.0E-02	1.0E-03 to 5.0E-05	2.9E-04 PE-Ci	6.8E-03 rem (MEI)
	3. Design-basis earthquake in the storage dome with multiple drum spill (3% of 16,655 drums in the facility spilled)	5.0E-01	1.0E-03 to 5.0E-05	1.2E-02 PE-Ci	2.9E-02 rem (MEI)
	4. Drum fire in the retrieval dome (beyond-design-basis accident)	1.0	5.0E-04	1.5E-01 PE-Ci	1.4 rem (MEI)
INEL SAR for Waste Storage Facility (EG&G, 1994b)	1. Drum fire/explosion (maximum credible design basis accident)	1.0	1.0E-03	1.2E-03 Ci	5.0E-02 rem (MEI)
	2. Box spill (1 box = 15 drums)	1.0E-01	1.0E-04	1.8E-03 Ci	4.2 rem (worker)
	3. Beyond design basis tornado with breach of 1,440 drums and 576 boxes	1.0E-01 (drums) 1.0 (boxes)	1.0E-04	1.2 Ci	9.7E-02 rem (MEI)
SRS Draft EIS (DOE, 1995)	1. Drum rupture and fire	Not available	Not available	Not available	7.2E-04 rem (MEI)
	2. Drum fire in culvert	Not available	Not available	Not available	2.4E-01 rem (MEI)
	3. Fire caused by vehicle crash (28 drums)	Not available	Not available	Not available	4.4E-02 rem (MEI)
	4. Drum deflagration in culvert during drum retrieval	Not available	Not available	Not available	5.7E-02 rem (MEI)
ORNL SAR for Waste Storage Facility, Bldg. 7574 (ORNL, 1994)	1. Earthquake with spill of drums (67% of 1,200 drums breached)	25% (10% of inner packages, if doubly packaged)	8.8E-07 to 1.0 E-03	Not available	5.0E-01 rem (MEI)
	2. Fire (12 drums)	1.0 (liquid) 0.5 (solid)	1.1E-01 (liquid) to 5.3E-04 (solid)	Not available	1.0E-01 rem (MEI)

Table F.4–1 Representative Accidents and Source Term Parameters from Recent DOE Safety Analysis Documents Relevant to TRUW Storage–Continued

Safety Document	Scenario	DF[a]	ARF or RARF[b]	Release	Consequence
Hazard Classification and Preliminary Safety Evaluation (PSE) for WRAP Module 2 (WHC, 1991a)	Seismic impacts with fire in incoming storage area (size reduction)	1.0	5.3E-04	2.1E-01 PE-Ci	3.0E-01 rem (MEI)
WRAP PSE (WHC, 1991b)	1. Seismic impacts with fire in shipping and receiving area (19% of 100 drums and 4 boxes)	1.9E-01	5.3E-04	5.9E-01 PE-Ci	Not available
	2. Drum/package spill (2 drums)	0.5 (1st drum) 0.25 (2nd drum)	1.0E-04 (1.0E-07 if filtered)	3.7E-06 PE-Ci	6.0E-03 rem (MEI)
INEL EIS (EG&G, 1994a)	1. Lava flow in TSA[e] (52,000 stored drums and 5.5E+04 m^3 soil covered)	0.25 to 0.75	1.0E-04 to 1.0E-07	2.7 Ci	Not available
	2. Aircraft crash into HFEF[f] WIPP waste (46 drums)	5.0E-01	2.5E-04	1.4E-02Ci	Not available
RWMC SAR (EG&G, 1993b)	1. Earthquake-initiated breach at TSA (65,443 drums)	1.0E-02	1.0E-03	7.4E-01 Ci	1.8E+00 rem (MEI)
	2. Fuel air explosion and fire at TSA	2.01E-01 (explosion) 5.0E-02 (fire)	1.0E-03 (explosion) 5.0E-04 (combustibles) 1.0E-05 (noncombustibles)	1.3E+01 Ci	3.2E+01 rem (MEI)
	3. Medium fire at ASB II[g] caused by propane pipe leak (9,455 drums)	1.0E-02	5.0E-04 (combustibles) 1.0E-05 (noncombustibles)	2.0E-02 Ci	4.8E-02 rem (MEI)
	4. Helicopter crash causing a large fire at ASB II (9,455 drums)	5.0E-02	5.0E-04 (combustibles) 1.0E-05 (noncombustibles)	9.7E-02 Ci	2.3E-01 rem (MEI)

[a] DF = damage fraction.
[b] ARF = airborne release fraction; RARF = respirable airborne release fraction.
[c] PE-Ci = Pu-239-equivalent curies.
[d] Maximally exposed individual off site.
[e] TSA = TRUW Storage Area.
[f] HFEF = Hot Fuel Examination Facility at ANL-W.
[g] ASB II = Air Support Building II.

lead to a fire or explosion. LANL neither analyzed a fire in the storage dome nor provided a rationale for not doing so. The source terms for accidents involving multiple containers are evaluated, assuming that the contents of the containers are distributed the same as those of the entire population of containers (average drums). The toppling accident due to an earthquake is assumed to only involve

drums stacked on the third level. Furthermore, to determine the number of drums at risk, the number of containers stacked at the third level is reduced by almost 90 percent due to interferences in the storage dome. Throughout the PSAR, inventories are expressed in terms of Pu-239-equivalent curies (PE-Ci). Consequences to the MEI at the site boundary were as follows: 1.7E-02, 6.8E-03, 2.9E-02, and 1.4 rem for drum spill, forklift puncture in crate, multiple drum spill caused by earthquake, and drum fire, respectively. The drum spill and forklift puncture in the crate were considered to be anticipated accidents with frequencies greater than 1.0E-02/yr. The earthquake accident was considered to be unlikely, with a frequency range between 1.0E-02 and 1.0E-04/yr. The beyond-design-basis drum fire was not considered credible, with a frequency of less than 1.0E-06/yr.

The INEL SAR for the Waste Storage Facility identifies three bounding accidents, including a drum fire and explosion, a box spill, and a tornado causing the breach of a large number of waste containers. An earthquake accident is identified but judged to be bounded by the tornado accident. The concentration of the drum content was averaged to be 0.16 Ci/cubic feet (ft^3) for a total drum activity of 1.176 Ci. However, for the box spill accident, the content is taken to be 10 times higher in concentration. It is estimated that 99 percent of the boxes at INEL are below this value (a box is equivalent to 15 drums in volume). A box spill accident is estimated to have a frequency of 1.2E-01/yr. The drum fire and explosion accident is considered to be the maximum bounding accident within design basis and is estimated to have a frequency of 2.0E-06/yr. The tornado accident is considered to be a beyond-design-basis accident with a frequency of 1.0E-07/yr. The consequence to the MEI at the site boundary for a tornado accident is estimated to be 9.7E-02 rem.

The accidents considered in the DOE Programmatic Spent Nuclear Fuel and INEL Environmental Restoration Waste Management EIS (EG&G 1994a) involving TRUW are a lava flow over the entire RWMC and an aircraft crash. The molten lava flow caused by a volcanic eruption was determined to be a reasonable foreseeable bounding accident with an estimated frequency of 2.0E-05/yr. Although the RWMC includes waste management operations involving LLMW, LLW, and TRUW, the results shown in Table F.4-1 are for CH-TRUW stored in the Transuranic Storage Area (TSA) inside the inflated Air Support Weather Shield buildings. TRUW at TSA consists of approximately 10,400 m^3 stored in drums (52,000 drums) and 55,000 m^3 of soil covered waste. The waste is assumed to come into direct contact with the lava. A two-phased release is assumed to take place. In the first phase, the combustible fraction of the waste is assumed to burn with a release fraction similar to a sustained fire. In the second phase, the remaining waste (noncombustible) is assumed to be mixed with the molten lava resulting in a release similar to off-gassing from a vitrification process. The aircraft accident in the

INEL EIS assumes that a large commercial jet crashes into the Hot Fuel Examination Facility (HFEF) at ANL-W. This accident is considered to be the bounding externally initiated event because it could cause a major breach of barriers, involve a large MAR, and have a high-energy stress of impact followed by fire. The frequency of this accident is estimated to be in the range of 1.0E-06 to 1.0E-08 per year. The waste present in the HFEF includes 20 fresh fuel assemblies, 50 stored subassemblies, and 46 drums of WIPP TRUW. However, the results presented in Table F.4–1 are pertinent to WIPP TRUW only. The number of drums affected by the crash is assumed to be 23 with an ARF of 5.0E-04 and RF of 5.0E-01.

The SRS EIS (DOE, 1995) identifies four representative bounding accidents associated with management of TRUW. These accidents include an internally induced drum rupture and fire, a drum fire in the culvert, a vehicle crash causing a drum fire, and a deflagration event in the culvert during TRUW retrieval activities involving a single drum. The SRS EIS reports consequence results for these accidents but does not include releases and source term parameters such as DFs, ARF, and RARF. All these accidents except the vehicle crash involve a single drum on the basis of the assumption that the other drums are sealed with a gasket and the lids are secured with metal ring clamps, and, therefore, the fire would not propagate to these drums. The internally induced drum rupture and fire is assumed to occur because of overpressurization due to gas buildup from radiolytic decomposition of cellulosic waste and the ignition of the generated hydrogen. The frequency of such an accident is estimated to be 2.1E-02/yr. The drum fire in the culvert is also assumed to be caused by hydrogen gas generated through radiolytic decomposition of organic waste and is estimated to have a frequency of 8.1E-04/yr. The vehicle crash with resulting fire at the TRUW storage pads is assumed to involve 28 drums with an estimated frequency of 6.5E-05/yr. The drum deflagration in the culvert is assumed to be caused by a flammable gas mixture of hydrogen and air that could exist inside a drum as the result of radiolysis of polyethylene wrappings. This accident is estimated to have a frequency of 1.0E-02/yr.

The ORNL SAR for the Waste Storage Facility, Building 7574 (ORNL, 1994) identifies two events as the worst-case bounding accidents: spill of drums caused by earthquake and fire inside the building affecting a stack of drums. Building 7574 at ORNL is used to store TRUW and solid LLW. The waste may contain liquids and powders. Some of the waste may be placed in plastic liners inside the drums. The maximum number of drums that can be stored in the building is 1,200. These drums are stored in four drums per pallet and stacked three pallets high. In the earthquake accident, only 67 percent of the total number of drums is assumed to be breached (the second and third levels). Twenty-five percent of the drum content is assumed to be spilled. If the waste is placed in a plastic liner, then only 10 percent

is assumed to be spilled. The frequency of an earthquake causing waste containers to fall is considered to be in the range of 1.0E-02 to 1.0E-04 per year. The consequence to an individual at the boundary of the site is estimated to be less than 0.5 rem for this accident. The fire accident inside the building is assumed to affect up to one stack of 12 drums. Liquid waste is considered to be flammable and to burn completely. The remainder of the waste is assumed to be 50 percent combustible. The frequency of a fire accident is considered to be unlikely in the range of 1.0E-02 to 1.0E-04/yr. The consequence from such an accident to the individual at the boundary of the site is estimated to be less than 0.1 rem. Release in terms of curies is not reported in this SAR.

The Waste Receiving and Packaging (WRAP), as originally configured, was designed to be constructed as a series of modules including units to process contact handled (Module 1) and remote handled (Module 2) TRU waste. A subsequent project reconfiguration resulted in redefinition of the module missions such that module 2 would have been intended to handle and treat radioactive mixed waste (as discussed below). A Hazard Classification and Preliminary Safety Evaluation (WHC, 1991a) identified and analyzed a set of accident scenarios to characterize the range of potential hazards attendant upon WRAP Module 1 operation. Consistent with DOE guidance on hazard class determination, the range of accidents analyzed included worst case scenarios resulting in completely unmitigated releases. The accident scenarios addressed both waste treatment and packaged waste lag storage and included drum spill, metal box drop and breach, liquid spill from waste pump, drop of a failed HWVP melter, and the most applicable one to the Waste EIS, a design basis earthquake (DBE). The applicable portion of the WRAP 2 scenario is the earthquake-initiated fire in the size reduction area (the Incoming Storage area). A release fraction of 5.3E-4 is assumed for the fire affecting 30 drums in the lag storage area. A maximally exposed offsite individual is estimated to receive a dose of 0.3 rem with an accident frequency of 1.0E-03/yr. No credit is taken in for HEPA filtration.

In a precursor report (WHC, 1991b), the prototype concept of a WRAP facility was analyzed for the effects of a BDBE. In the preconceptual design phase, the WRAP I module was scoped to handle and process contact-handled TRU. The Shipping and Receiving area was scoped to provide lag storage for 100 drums and 4 boxes. The waste packages are damaged by falling girders and portions of the roof. Based on estimates of debris and geometry of the storage array, 19% of the waste packages are estimated to be breached. The resulting fire is assumed to result in a release fraction of 5.3E-04. Aggregate dose consequences were estimated for the total facility release, but no estimates were provided for the contribution from Lag Storage.

In reviewing the cited analyses, it can be observed that there is considerable variation in the assumptions used by the various DOE sites to develop accidents and associated source term parameters. However, it appears from the analyses that overall, the risks to the public health resulting from storage facility accidents would be small, although the predicted releases are greater than those from LLMW accidents (see Section 6).

The final draft of the WM PEIS will use a systematic and internally consistent set of assumptions for analysis of facility accidents at all sites. However, the latest information from the aforementioned references will be used to guide the development of the accidents and the calculations of the appropriate source terms. The WM PEIS analyses for TRUW treatment facilities will be similar to those discussed in the chapters for LLW and LLMW accidents. Finally, the handling accidents affecting CH-TRUW will be analyzed in a manner similar to that for analyzing CH-LLW and CH-LLMW. Treatment facility and handling accidents will all be included in the final draft of the WM PEIS.

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F.5 Low-Level Waste

F.5.1 ALTERNATIVES AND SITES ANALYZED

The LLW WM alternatives in the WM PEIS are summarized in Table F.5-1. Calculational source term results for all of these alternatives are discussed herein.

Specifically excluded is evaluation of Greater-Than-Class-C (GTCC) LLW. The DOE program for GTCC LLW consists of three phases: (1) continuation of limited interim storage of (primarily) sealed sources, (2) providing a centralized dedicated storage facility until an NRC-licensed facility is available, and (3) disposal in either a HLW repository or a separate NRC-licensed facility. Because the DOE has not yet initiated efforts on an NRC-licensed facility, the current program assumes disposal in the HLW repository. Nuclear utility volumes will be needed to define phase 2 centralized storage requirements, potential packaging and treatment requirements, and fee specifications. The dedicated and interim storage phases could be merged, depending on commercial reactor decommissioning decisions. The WM PEIS only considers alternatives for current interim storage of sealed sources, namely:

- *No Action*. Continue to store limited quantities of commercial GTCC at Hanford, Fernald Environmental Management Project (FEMP), INEL, LANL, Oak Ridge Reservation (ORR), and SRS in existing and approved storage facilities.
- *Decentralization*. Continue the No Action alternative, and either expand existing or establish new interim storage facilities at DOE sites as may be required for additional limited commercial quantities (for example, in response to an emergency request by the NRC).
- *Regionalization*. Same as decentralization, except ship and store at a limited number of DOE sites (probably between two and five) until an appropriate disposal facility is available.
- *Centralization*. Same as decentralization, except ship and store at one DOE site until an appropriate disposal facility is available.

Current projected volumes of sealed sources (on the order of a few cubic meters) are uncertain with regard to the mix of compositions that will be received but are expected to be a minimal fraction of the total volume provided by utility waste. Independent of the mix of sealed sources received, the facility accident potential will be small because the source material form is physically and chemically stable, most sources are doubly encapsulated in stainless steel, quantities are relatively small, and the sources will probably be stored in their shipping packages. Because these packages will meet U.S. Department

Table F.5-1. Programmatic Alternatives for LLW Management[a]

WM PEIS Alternative[b]	Action	Hanford	LLNL	NTS	INEL	RFETS	LANL	Pantex	PGDP	FEMP	PORTS	SRS	ORR	Other
No action: all sites treat using existing capabilities; disposal at 6 sites	Treat at all	T[c]	T	T	T	T	T	T	T	T	T	T	T	T
	Dispose at 6	D[d]	-[e]	D	D	-	D	-	-	-	-	D	D	-
Decentralized treatment: stabilization at all sites	Treat at all	T	T	T	T	T	T	T	T	T	T	T	T	T
Decentralized	Dispose at 16	D	D	D	D	D	D	D	D	D	D	D	D	T
Regionalized 1	Dispose at 12	D	D	D	D	D	D	D	D	D	D	D	D	D
Regionalized 3	Dispose at 6	D	-	D	D	-	D	-	-	-	-	D	D	D
Regionalized 6	Dispose at 2	D	-	-	-	-	-	-	-	-	-	D	-	-
Regionalized 7	Dispose at 2	-	-	D	-	-	-	-	-	-	-	D	-	-
Centralized 1	Dispose at 1	D	-	-	-	-	-	-	-	-	-	-	-	-
Centralized 2	Dispose at 1	-	-	D	-	-	-	-	-	-	-	-	-	-
Decentralized treatment: stabilization at all sites														
Volume reduction at 11 sites	Treat at 11	T	T	-	T	T	T	T	T	T	T	T	T	-
Regionalized 2	Dispose at 12	D	D	D	D	D	D	D	D	D	D	D	D	-
Regionalized treatment: stabilization at all sites														
Volume reduction at 7 sites	Treat at 7	T	-	-	T	T	-	-	-	-	-	T	T	-
Regionalized 4	Dispose at 6	D	-	D	D	-	D	-	-	-	-	D	D	-
Centralized 3	Dispose at 1	D	-	-	-	-	-	-	-	-	-	-	-	-
Centralized 4	Dispose at 1	-	-	D	-	-	-	-	-	-	-	-	-	-
Volume reduction at 4 sites	Treat at 4	T	-		T	-		-	-	-	-	T	T	-
Regionalized 5	Dispose at 6	D	-	D	D	-	D	-	-	-		D	D	
Centralized treatment and disposal:	Treat at 1	T	-	-	-	-	-	-	-	-	-	-	-	-
Centralized 5	Dispose at 1	D	-	-	-	-	-	-	-	-	-	-	-	-
Sensitivity analyses[f]	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[a] PGDP = Paducah Gaseous Diffusion Plant; and PORTS = Portsmouth Gaseous Diffusion Plant.

[b] The WM PEIS considers four alternatives: no action, decentralized, regionalized, and centralized. This table provides an abbreviated case description and treatment (T) and disposal (D) codes for each of the 12 highest volume sites. The no action alternative is based on all sites using existing and planned and approved treatment facilities and disposing at the 6 disposal sites in accordance with current arrangements. The remainder of the table illustrates the variations of the decentralized, regionalized, and centralized alternatives for both treatment and disposal. Wastewater treatment and stabilization are assumed to take place at all sites. Volume reduction treatment techniques, such as incineration, compaction, and supercompaction, are coupled with stabilization for decentralized, regionalized, and centralized alternatives. Disposal is then considered at 1, 2, 6, 12, or 16 sites. Analysis of all of the alternative combinations of treatment and disposal provides the basis for the comparison of the WM PEIS alternatives.

[c] T = treatment.

[d] D = disposal.

[e] Not applicable.

[f] Sensitivity analyses considered three treatment variations, including vitrification, simple compaction (versus supercompaction), and volume reduction without incineration, and varied engineered disposal options (near-surface burial versus aboveground vaults).

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of Transportation (DOT) and NRC requirements, the packages will already be designed to withstand severe accidents.

Because of (1) the overall programmatic uncertainties, (2) the fact that utility waste inventories will undoubtedly dictate future facility accident impacts, and (3) the relatively small contribution of sealed source storage accidents to risk, accident source terms for current DOE interim storage of sealed sources were not developed.

F.5.2 Risk-Dominant Accidents and Modeling Considerations

Accident selection has been based on importance to risk, with the general modeling assumptions and related source term parameters described in Section F.2.2. LLW is generally rags, papers, filters, discharged protective clothing, and other materials contaminated with small amounts of radioactivity that are susceptible to fire-initiated events. The general modeling assumptions and related parameters for radiological source terms are detailed in Section F.2.

F.5.2.1 Handling Accidents

Storage or staging operations and related handling accidents were investigated because they are expected to dominate the exposure risk to workers due to their frequency and to the proximity of the workers to waste in hands-on operations. Representative handling accidents involve a single drum and assume that 25% of the drum inventory is affected and subject to stresses capable of rendering the contents airborne.

Although the inventories, physical forms, and radiological compositions of waste stored at each site were characterized in the WM PEIS and stored in a database, compilation of detailed information for individual operations and facilities on each site was beyond the scope of the WM PEIS. Accordingly, handling accidents assume a single site-dependent radiological and physical composition derived by volume-weighting the inventories of the treatability categories within each waste type, based on waste generation and inventory data at each site. Since each site is assumed to store only its own waste, the source terms associated with these handling accidents will not change from one alternative to another.

F.5.2.2 Storage Facility Accidents

Accidents and source terms for current storage were not analyzed because the results will not help to discriminate among alternatives. This results from the underlying assumption used in the PEIS analyses that all sites will accumulate or at least not reduce these inventories for roughly ten years at which time complex-wide treatment will begin. Thus all sites will achieve their maximum inventories (leading to maximum poential releases during a storage facility accident), independent of alternative. However, recent DOE safety reports and NEPA information are cited in Section 6 to provide guidance on the potential risk impacts applicable to LLMW storage facility accidents. This same information can be used to evaluate the anticipated risks of LLW storage facility accidents. Based on the available information, this risk for LLW storage accidents should be very low.

F.5.2.3 Treatment Facility Accidents

Incineration has been assessed as the treatment technology most likely to dominate risk to facility and site staff, as well as to the surrounding general populations. Severe radiological accidents investigated here are focused on sequences involving fire and explosions capable of producing large airborne releases of the highly dispersible ash present in storage or in the filtration systems of incinerators.

A generic treatment facility, consisting of a series of linked process modules, each providing a specific treatment process, was defined to assess accidents to envelop the releases from treatment process accidents (see Section 2). A DOE Hazard Category of 2 and concomitant structural performance requirements on its systems were assumed. Double HEPA filtration systems were assumed to be in place. The inventory was based on the facility throughput at each site. Volumetric inventories and physical, chemical, and radiological compositions for each waste treatability category were considered at each site for each alternative.

Accidents investigated included operation-induced facility fires and external-event-induced fires and explosions. Treatment facility accident sequences analyzed include:

- A fire in the baghouse area of the incineration facility causing a complete failure of the filtration systems (LPF = 1) with a fraction of 3.0E-02 of the total amount of ash existing in the facility (DF = 3.0E-02);

- A rotary kiln explosion caused by combustible gas buildup that affects the ash existing in the rotary kiln (a fraction of 1.2E-01 of the total in the facility; DF = 1.2E-01) and partially degrades the filtration system of the facility (LPF = 1.0E-03); and
- External events leading to a fire. All external-event source term parameters vary according to the particular sequence.

All accidents are assumed to be ground releases without filtration with the exception of the rotary kiln explosion accident where a stack emission and partial HEPA filtration is assumed with a remaining efficiency of 99.9% (LPF = 1.0E-03); therefore, the intrafacility source term used to determine worker risk is 1,000 times the atmospheric source term.

F.5.3 RESULTS

Preliminary results of the accident sequences described above for various site consolidation cases within each WM PEIS alternative were reviewed for risk dominance using the frequency-weighted dose to the MEI. The results were then grouped into four annual frequency categories: likely (>1.0E-02), unlikely (between 1.0E-02 and 1.0E-04), extremely unlikely (between 1.0E-04 and 1.0E-06), and not credible (<1.0E-06). Representative source terms for the important sequences were then selected as the bases for health effects calculations. Of the treatment technologies, only source terms for incineration facility accidents are provided because they were found to bound other treatment accidents, including vitrification, which resulted in atmospheric releases much lower than analogous incineration accidents.

The WM LLW accidents analyzed here are listed in Table F.5.2. Fourteen cases are considered for WM LLW alternatives, including Cases 1-9, 12, 14, 14a, 19, and 21. Only cases that included incineration for treatment were analyzed; therefore, no treatment process or facility was analyzed for Cases 2-8 in which all sites perform minimum treatment. Cases 12 (Regionalized 5), 14 (Centralized 3), and 14a (Centralized 4) involve treatment at seven sites with various disposal sites. These cases are equivalent with respect to the risk-dominant treatment technologies and amount of

Table F.5-2. Summary of WM LLW Accidents Analyzed[a]

Function	WM PEIS[b] Alternative Case	Site	Operational Events: Handling Breaches	Operational Events: Facility Fire	Operational Events: Facility Explosion	External Events: Seismic	External Events: Large Aircraft	External Events: Small Aircraft
General Handling[c]								
	All	Hanford	X	-[d]	-	-	-	-
	All	INEL	X	-	-	-	-	-
	All	LANL	X	-	-	-	-	-
	All	LLNL	X	-	-	-	-	-
	All	ORR	X	-	-	-	-	-
	All	PGDP	X	-	-	-	-	-
	All	Pantex	X	-	-	-	-	-
	All	PORTS	X	-	-	-	-	-
	All	RFETS	X	-	-	-	-	-
	All	SRS	X	-	-	-	-	-
Incineration	1	INEL	-	X	X	X	X	-
	1	SRS	-	X	X	X	X	-
	9	FEMP	-	X	X	X	-	-
	9	Hanford	-	X	X	X	X	-
	9	INEL	-	X	X	X	X	-
	9	LANL	-	X	X	X	-	-
	9	LLNL	-	X	X	X	-	-
	9	ORR	-	X	X	X	-	-
	9	Pantex	-	-	-	-	-	-
	9	PORTS	-	X	X	X	-	-
	9	PGDP	-	X	X	X	-	X
	9	SRS	-	X	X	X	X	-
α-Incineration[e]	9	RFETS	-	X	X	X	-	X
Incineration	12	Hanford	-	X	X	X	X	-
	12	INEL	-	X	X	X	X	-
	12	LANL	-	X	X	X	-	-
	12	ORR	-	X	X	X	-	-
	12	PORTS	-	X	X	X	-	X
	12	RFETS	-	X	X	X	-	X
	12	SRS	-	X	X	X	X	-
α-Incineration[e]	12	RFETS	-	X	X	X	-	X
Incineration	19	Hanford	-	X	X	X	X	-
	19	INEL	-	X	X	X	X	-
	19	ORR	-	X	X	X	-	-
	19	SRS	-	X	X	X	X	-
α-Incineration[e]	19	INEL	-	X	X	X	X	-
Incineration	21	Hanford	-	X	X	X	X	-
α-Incineration[e]	21	Hanford	-	X	X	X	X	-

[a] Only one source term, generally corresponding to the risk-dominant sequence for each accident initiator, was considered.

[b] Fourteen cases are considered for WM LLW alternatives, including Cases 1-9, 12, 14, 14a, 19, and 21. Only cases that included incineration for treatment were analyzed; therefore, no treatment process or facility was analyzed for Cases 2-8 in which all sites perform minimum treatments. Cases 12 (Regionalized 5), 14 (Centralized 3), and 14a (Centralized 4) involve regionalized treatment at seven sites with various disposal sites. These cases are equivalent with respect to the risk-dominant treatment technologies and amount of waste throughput at each site; therefore, only Case 12 was analyzed. The WM PEIS cases analyzed are described as follows:

- *Case 1 (No Action).* All sites treat LLW by using existing, planned, and approved treatment facilities and dispose of LLW at the 6 current disposal sites in accordance with current arrangements. Two sites (INEL and SRS) incinerate.
- *Case 9 (Regionalized 2).* Eleven sites (Hanford, INEL, LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS) incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all sites minimally treat other waste; disposal is at 12 sites (Hanford, INEL, NTS, LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS).
- *Case 12 (Regionalized 4).* Seven sites (Hanford, INEL, LANL, ORR, PORTS, RFETS, and SRS) incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all sites minimally treat other waste; disposal is at 6 sites (Hanford, INEL, NTS, LANL, ORR, and SRS).
- *Case 19 (Regionalized 5).* Four sites (Hanford, INEL, ORR, and SRS) incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all sites minimally treat other waste; disposal is at 6 sites (Hanford, INEL, NTS, LANL, ORR, and SRS).
- *Case 21 (Centralized 5).* One site (Hanford) incinerates, supercompacts, reduces the size of, and grouts volume-reducible waste; all sites minimally treat other waste; disposal is at 1 site (Hanford).

[c] The 10 major storage sites were selected for handling accidents; FEMP is not included here because it is an ER site.

[d] "-" = not applicable.

[e] α-Incineration refers to incineration of waste categorized as alpha-emitting.

waste throughput at each site; therefore, only Case 12 was analyzed. The WM PEIS cases analyzed are described as follows:

- *Case 1 (No Action).* All sites treat LLW by using existing, planned, and approved treatment facilities and dispose of LLW at the 6 current disposal sites in accordance with current arrangements. Two sites (INEL and SRS) incinerate.
- *Case 9 (Regionalized 2).* Eleven sites (Hanford, INEL, LANL, Oak Ridge Reservation [ORR], SRS, PORTS, Paducah Gaseous Diffusion Plant [PGDP], Fernald Environmental Management Project [FEMP], Lawrence Livermore National Laboratory [LLNL], Pantex Plant [Pantex], and RFETS) incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all sites minimally treat other waste; disposal is at 12 sites (Hanford, INEL, Nevada Test Site [NTS], LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS).
- *Case 12 (Regionalized 4).* Seven sites (Hanford, INEL, LANL, ORR, PORTS, RFETS, and SRS) incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all sites minimally treat other waste; disposal is at 6 sites (Hanford, INEL, NTS, LANL, ORR, and SRS).
- *Case 19 (Regionalized 5).* Four sites (Hanford, INEL, ORR, and SRS) incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all sites minimally treat other waste; disposal is at 6 sites (Hanford, INEL, NTS, LANL, ORR, and SRS).
- *Case 21 (Centralized 5).* One site (Hanford) incinerates, supercompacts, reduces the size of, and grouts volume-reducible waste; all sites minimally treat other waste; disposal is at 1 site (Hanford).

Tables F.5.3 and F.5.4 summarize the radiological source term parameters and frequency groups for the accidents. Separate incineration facilities were assumed for treating alpha- and nonalpha-contaminated waste. Detailed radionuclide releases are provided in Mueller (1995).

Table F.5-3 Frequencies and Source Term Parameters for WM LLW Drum Handling Accidents

WM PEIS Alternative	Site	Accident	Frequency Bin (/yr) >1E-2	1E-4–1E-2	1E-6–1E-4	<1E-6	VMAR (m^3)	MAR (Ci)	DF	Total Release[a] (Ci)
All	Hanford	Drum handling breach	X	–[b]	–	–	2.0E-01	3.0E-01	0.25	4.3E-04
All	INEL	Drum handling breach	X	–	–	–	2.0E-01	2.1E-01	0.25	5.3E-05
All	LANL	Drum handling breach	X	–	–	–	2.0E-01	1.5E+01	0.25	2.1E+00*
All	LLNL	Drum handling breach	X	–	–	–	2.0E-01	2.1E+01	0.25	5.2E+00*
All	ORR	Drum handling breach	X	–	–	–	2.0E-01	1.4E-01	0.25	6.7E-05
All	PGDP	Drum handling breach	X	–	–	–	2.0E-01	6.0E-05	0.25	1.8E-08
All	Pantex	Drum handling breach	X	–	–	–	2.0E-01	1.2E-02	0.25	3.0E-03*
All	PORTS	Drum handling breach	X	–	–	–	2.0E-01	2.8E-06	0.25	6.4E-09
All	RFP	Drum handling breach	X	–	–	–	2.0E-01	1.1E-03	0.25	1.2E-06
All	SRS	Drum handling breach	X	–	–	–	2.0E-01	6.1E-01	0.25	4.8E-02*

[a] = mainly H-3 released.
[b] "–" = not applicable

Table F.5.4 Frequencies and Source Term Parameters for WM LLW Incineration Facility Accidents

WM PEIS Alternative[a]	Site	Accident Sequence	Frequency Bin (/yr) > 1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	< 1.0E-06	Waste Form of MAR	Source Term Parameters VMAR (m^3)	MAR (Ci)	DF	RARF[b]	LPF[b]	Total Release (Ci)
1	INEL	Explosion in the rotary kiln	X	-[c]	-	-	Combustible	4.3E-01	1.5E-01	1.2E-01	1.0E-01	1.0E-03	1.8E-06
1	INEL	Fire in the baghouse area	-	X	-	-	Combustible	4.3E-01	1.5E-01	3.0E-02	1.0E-02	1.0E-00	4.6E-05
1	INEL	Earthquake followed by fire and explosion	-	-	X	-	Combustible	4.3E-01	1.5E-01	2.0E-01	1.0E-01	1.0E-00	3.1E-03
1	INEL	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	4.3E-01	1.5E-01	3.0E-01	1.0E-01	1.0E-00	4.6E-03
1	SRS	Explosion in the rotary kiln	X	-	-	-	Combustible	3.6E-01	1.1E+00	1.2E-01	1.0E-01	1.0E-03	1.3E-05
1	SRS	Fire in the baghouse area	-	X	-	-	Combustible	3.6E-01	1.1E+00	3.0E-02	1.0E-02	1.0E-00	3.3E-04
1	SRS	Earthquake followed by fire and explosion	-	-	X	-	Combustible	3.6E-01	1.1E+00	2.0E-01	1.0E-01	1.0E-00	2.2E-02
1	SRS	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	3.6E-01	1.1E+00	3.0E-01	1.0E-01	1.0E-00	3.3E-02
9	FEMP	Explosion in the rotary kiln	X	-	-	-	Combustible	1.9E-01	2.8E-05	1.2E-01	1.0E-01	1.0E-03	3.3E-10
9	FEMP	Fire in the baghouse area	-	X	-	-	Combustible	1.9E-01	2.8E-05	3.0E-02	1.0E-02	1.0E-00	8.3E-09
9	FEMP	Earthquake followed by fire and explosion	-	-	X	-	Combustible	1.9E-01	2.8E-05	2.0E-01	1.0E-01	1.0E-00	5.6E-07
9	Hanford	Explosion in the rotary kiln	X	-	-	-	Combustible	9.7E-04	5.3E-02	1.2E-01	1.0E-01	1.0E-03	6.3E-07
9	Hanford	Fire in the baghouse area	-	X	-	-	Combustible	9.7E-04	5.3E-02	3.0E-02	1.0E-02	1.0E-00	1.6E-05
9	Hanford	Earthquake followed by fire and explosion	-	-	X	-	Combustible	9.7E-04	5.3E-02	2.0E-01	1.0E-01	1.0E-00	1.1E-03
9	Hanford	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	9.7E-04	5.3E-02	3.0E-01	1.0E-01	1.0E-00	1.6E-03
9	INEL	Explosion in the rotary kiln	X	-	-	-	Combustible	4.3E-01	1.5E-01	1.2E-01	1.0E-01	1.0E-03	1.8E-06
9	INEL	Fire in the baghouse area	-	X	-	-	Combustible	4.3E-01	1.5E-01	3.0E-02	1.0E-02	1.0E-00	4.6E-05
9	INEL	Earthquake followed by fire and explosion	-	-	X	-	Combustible	4.3E-01	1.5E-01	2.0E-01	1.0E-01	1.0E-00	3.1E-03
9	INEL	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	4.3E-01	1.5E-01	3.0E-01	1.0E-01	1.0E-00	4.6E-05
9	LANL	Explosion in the rotary kiln	X	-	-	-	Combustible	1.4E+00	9.6E+00	1.2E-01	1.0E-01	1.0E-03	1.2E-04
9	LANL	Fire in the baghouse area	-	X	-	-	Combustible	1.4E+00	9.6E+00	3.0E-02	1.0E-02	1.0E-00	2.9E-03
9	LANL	Earthquake followed by fire and explosion	-	-	X	-	Combustible	1.4E+00	9.6E+00	2.0E-01	1.0E-01	1.0E-00	1.9E-01
9	LLNL	Explosion in the rotary kiln	X	-	-	-	Combustible	6.9E-03	9.8E-01	1.2E-01	1.0E-01	1.0E-03	1.2E-05
9	LLNL	Fire in the baghouse area	-	X	-	-	Combustible	6.9E-03	9.8E-01	3.0E-02	1.0E-02	1.0E-00	2.9E-04
9	LLNL	Earthquake followed by fire and explosion	-	-	X	-	Combustible	6.9E-03	9.8E-01	2.0E-01	1.0E-01	1.0E-00	2.0E-02
9	ORR	Explosion in the rotary kiln	X	-	-	-	Combustible	6.1E-02	2.0E-02	1.2E-01	1.0E-01	1.0E-03	2.4E-07
9	ORR	Fire in the baghouse area	-	X	-	-	Combustible	6.1E-02	2.0E-02	3.0E-02	1.0E-02	1.0E-00	5.9E-06
9	ORR	Earthquake followed by fire and explosion	-	-	X	-	Combustible	6.1E-02	2.0E-02	2.0E-01	1.0E-01	1.0E-00	3.9E-04
9	PORTS	Explosion in the rotary kiln	X	-	-	-	Combustible	3.5E-01	1.8E-04	1.2E-01	1.0E-01	1.0E-03	2.1E-09
9	PORTS	Fire in the baghouse area	-	X	-	-	Combustible	3.5E-01	1.8E-04	3.0E-02	1.0E-02	1.0E-00	5.3E-08
9	PORTS	Earthquake followed by fire and explosion	-	-	X	-	Combustible	3.5E-01	1.8E-04	2.0E-01	1.0E-01	1.0E-00	3.5E-06

Table F.5.4 Frequencies and Source Term Parameters for WM LLW Incineration Facility Accidents—Continued

WM PEIS Alternative[a]	Site	Accident Sequence	Frequency Bin (/yr) >1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	<1.0E-06	Waste Form of MAR	Source Term Parameters VMAR (m^3)	MAR (Ci)	DF	RARF[b]	LPF[b]	Total Release (Ci)
9	PGDP	Explosion in the rotary kiln	X	-	-	-	Combustible	1.3E-01	1.5E-03	1.2E-01	1.0E-01	1.0E-03	1.8E-08
9	PGDP	Fire in the baghouse area	-	X	-	-	Combustible	1.3E-01	1.5E-03	3.0E-02	1.0E-02	1.0E-00	4.6E-07
9	PGDP	Earthquake followed by fire and explosion	-	-	X	-	Combustible	1.3E-01	1.5E-03	2.0E-01	1.0E-01	1.0E-00	3.0E-05
9	PGDP	Small aircraft impact with fire and explosion	-	-	-	X	Combustible	1.3E-01	1.5E-03	5.0E-02	1.0E-01	1.0E-00	7.6E-06
9	RFETS	Explosion in the rotary kiln	X	-	-	-	α-Combustible[d]	7.0E-01	1.5E-01	1.2E-01	1.0E-01	1.0E-03	1.8E-06
9	RFETS	Fire in the baghouse area	-	X	-	-	α-Combustible	7.0E-01	1.5E-01	3.0E-02	1.0E-02	1.0E-00	4.6E-05
9	RFETS	Earthquake followed by fire and explosion	-	-	X	-	α-Combustible	7.0E-01	1.5E-01	2.0E-01	1.0E-01	1.0E-00	3.1E-03
9	RFETS	Small aircraft impact with fire and explosion	-	-	-	X	α-Combustible	7.0E-01	1.5E-01	5.0E-02	1.0E-01	1.0E-00	7.7E-04
9	SRS	Explosion in the rotary kiln	X	-	-	-	Combustible	3.6E-01	1.1E+00	1.2E-01	1.0E-01	1.0E-03	1.3E-05
9	SRS	Fire in the baghouse area	-	X	-	-	Combustible	3.6E-01	1.1E+00	3.0E-02	1.0E-02	1.0E-00	3.3E-04
9	SRS	Earthquake followed by fire and explosion	-	-	X	-	Combustible	3.6E-01	1.1E+00	2.0E-01	1.0E-01	1.0E-00	2.2E-02
9	SRS	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	3.6E-01	1.1E+00	3.0E-01	1.0E-01	1.0E-00	3.3E-02
12	Hanford	Explosion in the rotary kiln	X	-	-	-	Combustible	7.8E-03	1.0E+00	1.2E-01	1.0E-01	1.0E-03	1.2E-05
12	Hanford	Fire in the baghouse area	-	X	-	-	Combustible	7.8E-03	1.0E+00	3.0E-02	1.0E-02	1.0E+00	3.1E-04
12	Hanford	Earthquake followed by fire and explosion	-	-	X	-	Combustible	7.8E-03	1.0E+00	2.0E-01	1.0E-01	1.0E+00	2.1E-02
12	Hanford	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	7.8E-03	1.0E+00	3.0E-01	1.0E-01	1.0E+00	3.1E-02
12	INEL	Explosion in the rotary kiln	X	-	-	-	Combustible	4.3E-01	1.5E-01	1.2E-01	1.0E-01	1.0E-03	1.8E-06
12	INEL	Fire in the baghouse area	-	X	-	-	Combustible	4.3E-01	1.5E-01	3.0E-02	1.0E-02	1.0E+00	4.6E-05
12	INEL	Earthquake followed by fire and explosion	-	-	X	-	Combustible	4.3E-01	1.5E-01	2.0E-01	1.0E-01	1.0E+00	3.1E-03
12	INEL	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	4.3E-01	1.5E-01	3.0E-01	1.0E-01	1.0E+00	4.6E-03
12	LANL	Explosion in the rotary kiln	X	-	-	-	Combustible	1.4E+00	9.6E+00	1.2E-01	1.0E-01	1.0E-03	1.2E-04
12	LANL	Fire in the baghouse area	-	X	-	-	Combustible	1.4E+00	9.6E+00	3.0E-02	1.0E-02	1.0E+00	2.9E-03
12	LANL	Earthquake followed by fire and explosion	-	-	X	-	Combustible	1.4E+00	9.6E+00	2.0E-01	1.0E-01	1.0E+00	1.9E-01
12	ORR	Explosion in the rotary kiln	X	-	-	-	Combustible	5.0E-01	2.1E-02	1.2E-01	1.0E-01	1.0E-03	2.6E-07
12	ORR	Fire in the baghouse area	-	X	-	-	Combustible	5.0E-01	2.1E-02	3.0E-02	1.0E-02	1.0E+00	6.4E-06
12	ORR	Earthquake followed by fire and explosion	-	-	X	-	Combustible	5.0E-01	2.1E-02	2.0E-01	1.0E-01	1.0E+00	4.3E-04
12	PORTS	Explosion in the rotary kiln	X	-	-	-	Combustible	2.3E-01	3.2E-05	1.2E-01	1.0E-01	1.0E-03	3.9E-10
12	PORTS	Fire in the baghouse area	-	X	-	-	Combustible	2.3E-01	3.2E-05	3.0E-02	1.0E-02	1.0E+00	9.6E-09
12	PORTS	Earthquake followed by fire and explosion	-	-	X	-	Combustible	2.3E-01	3.2E-05	2.0E-01	1.0E-01	1.0E+00	6.4E-07
12	PORTS	Small aircraft impact with fire and explosion	-	-	-	X	Combustible	2.3E-01	3.2E-05	5.0E-02	1.0E-01	1.0E+00	1.6E-07
12	RFETS	Explosion in the rotary kiln	X	-	-	-	Organic	1.0E-03	2.2E-04	1.2E-01	1.0E-01	1.0E-03	2.6E-09
12	RFETS	Fire in the baghouse area	-	X	-	-	Organic	1.0E-03	2.2E-04	3.0E-02	1.0E-02	1.0E+00	6.6E-08
12	RFETS	Earthquake followed by fire and explosion	-	-	X	-	Organic	1.0E-03	2.2E-04	2.0E-01	1.0E-01	1.0E+00	4.4E-06
12	RFETS	Small aircraft impact with fire and explosion	-	-	-	X	Organic	1.0E-03	2.2E-04	5.0E-02	1.0E-01	1.0E+00	1.1E-06
12	SRS	Explosion in the rotary kiln	X	-	-	-	Combustible	3.6E-01	1.1E+00	1.2E-01	1.0E-01	1.0E-03	1.3E-05
12	SRS	Fire in the baghouse area	-	X	-	-	Combustible	3.6E-01	1.1E+00	3.0E-02	1.0E-02	1.0E+00	3.3E-04
12	SRS	Earthquake followed by fire and explosion	-	-	X	-	Combustible	3.6E-01	1.1E+00	2.0E-01	1.0E-01	1.0E+00	2.2E-02
12	SRS	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	3.6E-01	1.1E+00	3.0E-01	1.0E-01	1.0E+00	3.3E-02

Table F.5.4 Frequencies and Source Term Parameters for WM LLW Incineration Facility Accidents—Continued

WM PEIS Alternative[a]	Site	Accident Sequence	Frequency Bin (/yr) > 1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	< 1.0E-06	Waste Form of MAR	Source Term Parameters VMAR (m^3)	MAR (Ci)	DF	RARF[b]	LPF[b]	Total Release (Ci)
12	RFETS	Explosion in the rotary kiln	X	-	-	-	α-Combustible	7.0E-01	1.5E-01	1.2E-01	1.0E-01	1.0E-03	1.8E-06
12	RFETS	Fire in the baghouse area	-	X	-	-	α-Combustible	7.0E-01	1.5E-01	3.0E-02	1.0E-02	1.0E-00	4.6E-05
12	RFETS	Earthquake followed by fire and explosion	-	-	X	-	α-Combustible	7.0E-01	1.5E-01	2.0E-01	1.0E-01	1.0E-00	3.1E-03
12	RFETS	Small aircraft impact with fire and explosion	-	-	-	X	α-Combustible	7.0E-01	1.5E-01	5.0E-02	1.0E-01	1.0E+00	7.7E-04
19	Hanford	Explosion in the rotary kiln	X	-	-	-	Combustible	7.8E-03	1.0E+00	1.2E-01	1.0E-01	1.0E-03	1.2E-05
19	Hanford	Fire in the baghouse area	-	X	-	-	Combustible	7.8E-03	1.0E+00	3.0E-02	1.0E-02	1.0E-00	3.1E-04
19	Hanford	Earthquake followed by fire and explosion	-	-	X	-	Combustible	7.8E-03	1.0E+00	2.0E-01	1.0E-01	1.0E-00	2.1E-02
19	Hanford	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	7.8E-03	1.0E+00	3.0E-01	1.0E-01	1.0E-00	3.1E-02
19	INEL	Explosion in the rotary kiln	X	-	-	-	Combustible	1.8E+00	9.8E+00	1.2E-01	1.0E-01	1.0E-03	1.2E-04
19	INEL	Fire in the baghouse area	-	X	-	-	Combustible	1.8E+00	9.8E+00	3.0E-02	1.0E-02	1.0E-00	2.9E-01
19	INEL	Earthquake followed by fire and explosion	-	-	X	-	Combustible	1.8E+00	9.8E+00	2.0E-01	1.0E-01	1.0E-00	2.0E-01
19	INEL	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	1.8E+00	9.8E+00	3.0E-01	1.0E-01	1.0E-00	2.9E-01
19	INEL	Explosion in the rotary kiln	X	-	-	-	α-Combustible	7.0E-01	1.5E-01	1.2E-01	1.0E-01	1.0E-03	1.8E-06
19	INEL	Fire in the baghouse area	-	X	-	-	α-Combustible	7.0E-01	1.5E-01	3.0E-02	1.0E-02	1.0E-00	4.6E-05
19	INEL	Earthquake followed by fire and explosion	-	-	X	-	α-Combustible	7.0E-01	1.5E-01	2.0E-01	1.0E-01	1.0E 00	3.1E-03
19	INEL	Large aircraft impact with fire and explosion	-	-	-	X	α-Combustible	7.0E-01	1.5E-01	3.0E-01	1.0E-01	1.0E-00	4.6E-05
19	ORR	Explosion in the rotary kiln	X	-	-	-	Combustible	7.3E-01	2.1E-02	1.2E-01	1.0E-01	1.0E-03	2.6E-07
19	ORR	Fire in the baghouse area	-	X	-	-	Combustible	7.3E-01	2.1E-02	3.0E-02	1.0E-02	1.0E-00	6.4E-06
19	ORR	Earthquake followed by fire and explosion	-	-	X	-	Combustible	7.3E-01	2.1E-02	2.0E-01	1.0E-01	1.0E-00	4.3E-04
19	SRS	Explosion in the rotary kiln	X	-	-	-	Combustible	3.6E-01	1.1E+00	1.2E-01	1.0E-01	1.0E-03	1.3E-05
19	SRS	Fire in the baghouse area	-	X	-	-	Combustible	3.6E-01	1.1E+00	3.0E-02	1.0E-02	1.0E-00	3.3E-04
19	SRS	Earthquake followed by fire and explosion	-	-	X	-	Combustible	3.6E-01	1.1E+00	2.0E-01	1.0E-01	1.0E-00	2.2E-02
19	SRS	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	3.6E-01	1.1E+00	3.0E-01	1.0E-01	1.0E-00	3.3E-02
21	Hanford	Fire in the baghouse area	-	X	-	-	Combustible	2.9E+00	1.2E+01	3.0E-02	1.0E-02	1.0E-00	3.6E-03
21	Hanford	Earthquake followed by fire and explosion	-	-	X	-	Combustible	2.9E+00	1.2E+01	2.0E-01	1.0E-01	1.0E-00	2.4E-01
21	Hanford	Large aircraft impact with fire and explosion	-	-	-	X	Combustible	2.9E+00	1.2E+01	3.0E-01	1.0E-01	1.0E-00	3.6E-01
21	Hanford	Explosion in the rotary kiln	X	-	-	-	α-Combustible	7.0E-01	1.5E-01	1.2E-01	1.0E-01	1.0E-03	1.8E-06
21	Hanford	Fire in the baghouse area	-	X	-	-	α-Combustible	7.0E-01	1.5E-01	3.0E-02	1.0E-02	1.0E-00	4.6E-05
21	Hanford	Earthquake followed by fire and explosion	-	-	X	-	α-Combustible	7.0E-01	1.5E-01	2.0E-01	1.0E-01	1.0E-00	3.1E-03
21	Hanford	Large aircraft impact with fire and explosion	-	-	-	X	α-Combustible	7.0E-01	1.5E-01	3.0E-01	1.0E-01	1.0E-00	4.6E-03

Table F.5.4 Frequencies and Source Term Parameters for WM LLW Incineration Facility Accidents—Continued

[a] The WM PEIS cases analyzed are described as follows:

- *Case 1 (No Action)*. All sites treat LLW by using existing, planned, and approved treatment facilities and dispose of LLW at the 6 current disposal sites in accordance with current arrangements. Two sites (INEL and SRS) incinerate.
- *Case 9 (Regionalized 2)*. Eleven sites (Hanford, INEL, LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS) incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all sites minimally treat other waste; disposal is at 12 sites (Hanford, INEL, NTS, LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS).
- *Case 12 (Regionalized 4)*. Seven sites (Hanford, INEL, LANL, ORR, PORTS, RFETS, and SRS) incinerate, supercompact, reduce the size of, and grout volume--reducible waste; all sites minimally treat other waste; disposal is at 6 sites (Hanford, INEL, NTS, LANL, ORR, and SRS).
- *Case 19 (Regionalized 5)*. Four sites (Hanford, INEL, ORR, and SRS) incinerate, supercompact, reduce the size of, and grout volume-reducible waste; all sites minimally treat other waste; disposal is at 6 sites (Hanford, INEL, NTS, LANL, ORR, and SRS).
- *Case 21 (Centralized 5)*. One site (Hanford) incinerates, supercompacts, reduces the size of, and grouts volume-reducible waste; all sites minimally treat other waste; disposal is at 1 site (Hanford).

[b] Values shown are for particulate (nonvolatile) solids such as U-235 or Pu-238; see Appendix D.

[c] – = not applicable.

[d] α refers to treatment of waste categorized as alpha-emitting.

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F.6 Low-Level Mixed Waste

F.6.1 ALTERNATIVES AND SITES ANALYZED

The LLMW WM alternatives in the WM PEIS are summarized in Table F.6–1. Calculational source term results are discussed herein for the identified sites.

F.6.2 RISK-DOMINANT ACCIDENTS AND MODELING CONSIDERATIONS

The selection of accidents considers the importance to risk of both radiological and chemical hazards. The general modeling assumptions and related parameters for radiological source terms are detailed in Section F.2. Review of the hazardous contents of the wastes and their concentrations suggests that spills of organic liquids (WM PEIS treatment codes [TCs] 3 through 6), followed by evaporation or combustion reactions (or both), are the events most likely to lead to the airborne release of chemically hazardous substances. The possibility of fires is strongest in the wastestreams containing combustible organic substances in large proportions. Table F.6–2 summarizes the chemical release characteristics developed for the accidents (Mueller et al., 1995).

F.6.2.1 Handling Accidents

Handling accidents during the staging and storage of CH waste are expected to ominate the risk of exposure for workers because of the high frequency of such accidents and the proximity of the workers during hands-on operations. The frequencies of accidents at a given site would be a strong function of waste throughput at that site. The assumption used (see Section F.2.6.1) is that two severe breaches of containment occur per year for each inventory of 10,000 drums handled. It is assumed for the results herein that handling breaches fall in the >0.01/yr frequency category.

Representative radiological accident scenarios assume that a single drum is affected, such that 25 percent of its contents are rendered airborne (DF = 2.5E–01). The composition of the

Table F.6–1. Specification of LLMW Alternatives[a]

WM PEIS Alternative[b]	Action	Hanford	LLNL	ETEC	NTS	INEL	RFETS	LANL	Pantex	PGDP	FEMP	PORTS	ORR	Middlesex	SRS	Other
No action: LDR treatment at 3 sites.	Treat at all	-	-	-	-	T[c]	-	-	-	-	-	-	T	-	T	-
All sites store	Store at all	S[d]	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Decentralized: LDR treatment at 49 sites	Treat at all	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Disposal at 16 sites	Dispose at 16	D[e]	D	-[f]	D	D	D	D	D	D	D	D	D	D	D	-
Regionalized 1: LDR treatment at 11 sites	Treat at 11 + 2	T	T	T*[g]	-	T	T	T	T	T	T	T	T	T*	T	-
Disposal at 12 sites	Dispose at 12	D	D	-	-	D	D	D	D	D	D	D	D	D	D	-
Regionalized 2: LDR treatment at 7 sites	Treat at 7	T	-	-	-	T	T	T	-	-	-	T	T	-	T	-
Disposal at 6 sites	Dispose at 6	D	D	-	D	D	-	-	-	-	-	-	D	-	D	-
Regionalized 3: LDR treatment at 7 sites	Treat at 7	T	-		-	T	T	T	-	-	-	T	T	-	T	-
Disposal at 1	Dispose at 1	-	-	-	D	-	-	-	-	-	-	-	-	-	-	-
Regionalized 4: LDR treatment at 4 sites	Treat at 4	T	-	-	-	T	-	-	-	-	-	-	T	-	T	-
Disposal at 6 sites	Dispose at 6	D	-	-	D	D	-	D	-	-	-	-	D	-	D	-
Centralized: LDR treatment at 1 site	Treat at 1	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Disposal at 1 site	Dispose at 1	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sensitivity analyses[h]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[a] ETEC = Energy Technology Engineering Center; Middlesex = Middlesex Sampling Plant; NTS = Nevada Test Site.

[b] The EM PEIS considers four alternatives: no action, decentralized, regionalized, and centralized. This table provides an abbreviated case description and treatment (T) and disposal (D) codes for each of the 14 highest volume sites. The no action alternative is based on all sites using existing treatment facilities and placing the treated waste in monitored, aboveground storage facilities at all DOE sites. The decentralized treatment alternative analyzes LDR treatment at 49 sites disposal at 16 sites. Several regionalized treatment alternatives are considered, which include LDR treatment at 11, 7, or 4 sites, with disposal at either 12, 6, or 1 site(s). The centralized alternative analyzes treatment and disposal at only 1 site. The remote-handled alternative involves treatment and disposal at 4 sites.

[c] T = treatment.

[d] S = storage.

[e] D = disposal.

[f] Not applicable.

[g] T* = specialized treatment.

[h] Sensitivity analyses include examination of vitrification and nonthermal treatment options, engineered disposal options, the use of alternative characterization methods, and the consolidation of special wastestreams.

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Table F.6–2. Chemical Releases Analyzed for LLMW

Scenario	Toxic Gases Released[a]	Mass of Waste	Release Rate
Spill of aqueous nonhalogenated organic liquids (TC 4)	Acetone; butanone; methanol	160 lb/drum	2-3 lb/min[b]
Spill of aqueous halogenated organic liquid (TC 3)	Trichloroethanes; other chlorohydrocarbons	6 lb/drum	0.1 lb/min
Spill of "pure" halogenated organic liquids (TC 5)	Trichloroethanes Tetrachloroethanes	50 lb/drum 10 lb/drum	0.5 lb/min 0.1 lb/min
Spill of "pure" nonhalogenated organic liquids (TC 6)	Acetone; butanone; methanol BTX	60 lb/drum 200 lb/drum	1 lb/min[b] 2 lb/min[b]
Spill of "pure" nonhalogenated organic liquids (TC 6) followed by fire	BTX CO Cd fumes Cr compounds Soot	10 lb/drum 200 lb/drum 0.5 lb/drum 0.5-1.0 lb/drum 80 lb/drum	0.3 lb/min 7 lb/min 0.02 lb/min 0.02 lb/min 2.7 lb/min
Incinerator staging area fire involvement of TC 12 (organic sludges), 19 (combustible debris), organic liquid (intermediate), and organic particulates (intermediate)	CO HCl BTX fumes Soot Cd fumes (condensing to very small particles) Cr compounds	40-50% of mass of drum 60% of mass of Cl-containing compounds in the stream 5% of mass of BTX present 40% of mass of BTX plus 10% of total mass 100% of mass of Cd present 250% of mass of Cr present	7 lb/min/drum 2 lb/min/drum 0.3 lb/min/drum 3 lb/min/drum 0.02 lb/min/drum 0.02 lb/min/drum

[a] BTX = benzene, toluene, and xylene; Cd = cadmium; and Cr = chromium.
[b] An approximation to this release rate can be estimated from Salazar and Lane (1992):

$$QR = \frac{0.106^{0.78}\,(MW)^{0.667}\,(A)\,VP}{R\,(t + 273)}\ ,$$

where

QR = release rate pounds per minute (lb/min),
MW = molecular weight (g/mole [mol]),
A = surface area (square foot) (ft^2),
VP = effective vapor pressure (millimeter [mm] Hg),
R = 82.05 atm cm^3/mol K,
t = temperature (°C), and
μ = wind speed (m/second [s]).

The assumed options are that t = 30 °C, A = 220 ft^2, and wind speed = 2 m/s. For acetone in TC 4, MW = 58 g/mol, and VP = 0.36 × 285 mm Hg. For acetone in TC 6, VP = 0.14 × 285 mm Hg. For benzene in TC 6, MW = 78 g/mol, and VP = 0.44 × 120 mm Hg.

representative drum is taken as a volume-weighted average of the treatability category compositions (excluding aqueous streams) at each site.

Representative chemical releases assume a single drum with 100 percent (DF = 1.0E+00) of its contents spilled. The release characteristics for spills are described in the report by Mueller et al. (1995).

F.6.2.2 Storage Facility Accidents

Accidents for current storage were not analyzed because the results will not help to discriminate among alternatives. This results from the underlying assumption used in the PEIS analyses that all sites will accumulate or at least not reduce these waste inventories for roughly 10 years, at which time complex-wide treatment will begin. Thus, all sites will achieve their maximum inventories (leading to maximum potential releases), independent of alternative. However, because recent DOE safety or NEPA information on storage facility accidents provides guidance on the potential risk impacts applicable to storage, this information is discussed herewith.

Current SARs predict consequences for a range of selected waste storage accidents of varying frequency. Sometimes these accidents involve facilities which store primarily LLMW. A brief summary of some of these accidents involving LLMW, assumptions used by the sites in preparing the analyses, and release or health effect results are shown in Table F.6.3.

The INEL SAR for the Radioactive Waste Management Complex (RWMC) identifies three bounding accidents involving LLMW. All of these accidents occur at or involve in some manner the Air Support Building II (ASB-II), the facility which stores most of the LLMW at INEL. An accident with fire was identified as occurring at ASB-II and caused by a propane leak in the fuel line supplying the heat and inflation unit within the facility. This accident would involve only the waste stored at ASB-II resulting in an exposure of 2.0E-02 rem (MEI). A second accident was identified as initiated by an earthquake, sufficiently severe to damage all of the buildings (ASB-II included) at the RWMC. The radiological release and consequences listed in Table 6.5 for this accident (i.e., 0.041 Ci and 0.75 rem) is due primarily to wastes stored in buildings other than ASB-II. The third accident, a fuel-air explosion originating in ASB-II has the potential to release hazardous materials due primarily to the explosion and subsequent fire. However, a similar fuel-air explosion originating in the Certified and Segregated (C&S) Facility with the subsequent fire impacting all TSA facilities at the RWMC will bound the

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consequences of the fuel-air explosion originating at ASB-II. Because of this bounding condition the consequence analysis for the ASB-II accident was not performed. Table F.6.3 lists the parameters and results for the similar C&S bounding accident.

The RFETS SAR for the Central Waste Storage Facility (Building 906) identifies 3 accidents associated with LLMW. Each of these accidents assumes 8,300 drums of waste as the material at risk with each drum filled with waste to 50% of total volume. The void space is assumed to contain dust (at 100 mg/m^3) which is vented to the air upon breaching of the drum. Other variables of each accident type are given in Table F.6.3.

A PSE conducted for WRAP (Module 2) at Hanford identifies an accident scenario. An earthquake, including waste spills and fire, leads to a release of 0.041 Ci with a consequence of 3.9E-05 rem (MEI) with an accident frequency of 1.0E-03/yr (see Table F.6.3).

The International Technology Corporation (IT) has calculated the risks associated with the treatment, storage, and disposal of many types of LLMW. They have looked at many kinds of accidents related to the treatment, storage, and handling of these wastes. An example of a storage accident scenario is a fire within a container in the storage facility that might cause particulates in the waste to resuspend and be inhaled by workers. Members of the public might also be exposed to airborne effluents if building ventilation fails. IT Corporation has used a system analysis methodology to accumulate risk across different management options rather than breaking out the consequences and contaminant releases associated with a particular accident as the SARs usually do. This different approach to the problem has made comparison difficult with the more conventional approach of calculating the consequences of each separate accident. In general, IT has tended to look at sets of accidents of relatively high frequency with low consequences rather than the more standard approach of surveying accidents of very low frequency but with very high consequences.

In reviewing the cited analyses it was observed that there is considerable variation in the assumptions used by the various DOE sites to develop accidents and estimate associated source term parameters. However, it appears from the analyses that overall, the risks to the public health resulting from storage facility accidents would be small.

Table F.6–3 Representative Accidents and Source Term Parameters from Recent DOE Safety Analysis Documents Relevant to LLMW

Safety Document	Scenario	DF[a]	ARF or RARF[b]	Release (Ci)	Consequence (MEI[e]-rem)
RWMC SAR (EG&G, 1993b)	1. Propane Line Leak at ASB II Medium Fire	1.0E-02	5.0E-04 (combustible) 1.0E-02 (noncombustible)	2.0E-02	2.0E-02
	2. Earthquake initiating breach in CH LLW Pit and involving ASB II	1.0E-03	1.0E-03	4.1E-02	7.5E-01
	3. Fuel Air Explosion in ASB II, bounded by same type event in C&S Facility[c]	2.0E-01	1.0E-03 (numbers for a C&S event)	1.3E+01	3.2
Building 906 SAR Central Waste Storage Facility					
(RFETS, 1994)	1. Earthquake and Spill (Collapsed building) void space voulme of 8,300 drums (MAR) (assume drum ½ full)	1.0	1.0	3.37E-5 gr Pu	2E-06
	2. Spill from Impacts 100% void space vented (8,300 drums)	1.0	1.0	100 mg/m^3 particulate loading in void space	NA[d]
	3. Fire ruptures all exposed containers	100% burn of combustibles 18% ablation of noncombustibles	5.0E-4 particulate 1.0E-5 metals 1.0 liquids	varies with assumptioms about fire	NA[d]
Hazard Classification and Preliminary Safety Evaluation (PSE) for WRAP Module 2 (WHC, 1991a)	1. Earthquake and spill of dry waste and fire	1.0	5.3E-04	4.1E-02	3.9E-05

[a] DF = damage fraction.
[b] ARF = airborne release fraction; RARF = respirable airborne release fraction.
[c] C&S = Certified and Segregated Facility
[d] NA = not available.
[e] MEI = Maximally exposed individual off site.

F.6.2.3 Treatment Facility Accidents

Incineration was assessed as the treatment technology most likely to be important to risk to facility employees and the public. Radiological accident sequences involve severe fires and explosions that produce large airborne releases of the ash present in the incinerator area or in the filtration systems.

A generic treatment facility, consisting of a series of linked treatment process modules, is described in Section 2. A DOE Hazard Category of 2, concomitant system performance requirements, and double HEPA filtration systems were assumed. For each alternative, each waste treatability category at each site has a unique volumetric inventory and physical, chemical and radiological composition. Each incineration facility was assumed to have 1% of its annual incinerable LLMW throughput on-site at the time of the accident.

Accidents investigated included operation-induced facility fires and explosions, and external-event-induced fires and explosions. Treatment facility accident sequences analyzed include:

- A fire in the baghouse area of the incineration facility dispersing the dry ash in the filters (3% of the facility inventory; DF = 3.0E-02) and failing the filtration systems completely (LPF = 1),
- An incinerator explosion resulting from combustible gas buildup that disperses the ash in the rotary kiln (12% of facility inventory; DF = 1.2E-01) and partially degrades the filtration system (LPF = 1.0E-03), and
- External events leading to a fire.

All accidents are assumed to be ground releases without filtration, with the exception of the incinerator explosion where partial HEPA filtration and a stack emission are assumed. The LPF of 1.0E-03 results in the intrafacility source term used to determine worker risk equaling 1,000 times the atmospheric source term for this accident.

Wet-air oxidation was also analyzed because of the high treatment volumes at some of the sites. A rupture with a subsequent violent pressurized and unfiltered release to the atmosphere of the entire vessel contents was postulated as the only plausible sequence capable of producing any measurable consequences to site staff or the public. An earthquake that simultaneously breached the containment building was defined as the most likely initiator. Calculations were specifically performed for a limited set of alternatives and the resulting risk was found to be significantly lower than that for the incineration accidents. As a result, source terms for wet-air oxidation accidents were not used for health effects calculations.

Frequencies of accidents are consistent with those for the LLW analysis. The frequency of 1.5E-02/yr for explosions in the rotary kiln assembly and the secondary combustion chamber, respectively, provide the basis for the internal fire frequencies. The frequencies of aircraft-initiated accidents depend on the site. The annual frequency of a seismic event exceeding the design basis for a Hazard Category 2

facility is 1.0E-03/yr with the conditional probability of rupturing containment and initiating a fire estimated to equal 5.0E-02. Screening calculations of airplane accidents for the LLMW treatment facilities were performed and the risks were found to be much lower than the risk of an earthquake, or negligible. As a result, source terms for airplane accidents were not provided for health effects calculations.

The limiting chemical accident is assumed to be an operational fire in the feedstock staging area, which includes waste in processing and lag storage. The MAR was assumed to be 1% of annual throughput of the incineration facility as established by the WM PEIS alternative. A DF of 1.0E-01 was assumed to account for the presence of noncombustible material and the distribution of the combustible materials in areas other than the feedstock area. Because of the high frequency of internal fires compared with those caused by external events, only the operational fire was analyzed.

F.6.3 RESULTS

Preliminary results of the radiological accident sequences described above for various site consolidation cases within each WM PEIS alternative were reviewed for risk dominance using the frequency-weighted dose to the MEI, and then grouped into four annual frequency categories: likely (>1.0E-02), unlikely (between 1.0E-02 and 1.0E-04), extremely unlikely (between 1.0E-04 and 1.0E-06), and not credible (<1.0E-06). Representative source terms for the risk-dominant sequences were then selected as the bases for health effects calculations. Of the treatment technologies, only source terms for incineration facility accidents are provided because they were found to bound other treatment accidents, including wet-air oxidation, which resulted in atmospheric releases much lower than analogous incineration accidents. Chemical accident releases were also calculated.

No radiological source terms were estimated for the representative treatment facility chemical accident because they were determined to be unimportant to risk compared with radiological source terms for the reference radiological accident. Specifically, the radionuclide concentrations and dispersibility of the ash in the filter fire are much greater than for the feedstock fire and precludes the need for radiological source term calculations for the latter.

Similarly, no chemical source terms have been produced for the reference radiological accident because of their insignificance compared with the reference chemical accidents. Specifically, the toxic chemical concentrations in the incinerator feedstock fire are much higher than in the ash dispersed in the

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reference radiological accidents, precluding the need to calculate chemical source terms for the latter accident.

The waste management LLMW facility accidents analyzed here are summarized in Table F.6.4. Eight cases are considered for the WM LLMW alternatives: Cases 1, 2, 4, 7, 10, 15, 17, and 26. Cases 7 (Regionalized 2: seven sites treat, six sites dispose) and 10 (Regionalized 3: seven sites treat, one site disposes) are equivalent with respect to the risk-dominant treatment technologies and the amount of waste throughput at each site; therefore, only Case 7 was analyzed. Eight cases are considered for WM LLMW alternatives, including Cases 1, 2, 4, 7, 10, 15, 17 and 26. Case 7 (Regionalized 2: 7 sites treat, 6 sites dispose) and 10 (Regionalized 3: 7 sites treat, 1 site disposes) are equivalent with respect to the risk-dominant treatment technologies and the amount of waste at each site; therefore, only Case 7 was analyzed. The WM PEIS cases analyzed are described as follows:

- Case 1 (No Action). Three sites (INEL, ORR, and SRS) treat and store, all remaining sites store.
- *Case 2 (Decentralized).* Forty-nine sites treat, and 16 sites dispose.
- *Case 4 (Regionalized 1).* Eleven sites (Hanford, INEL, LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS) treat, and 12 sites dispose.
- *Case 7 (Regionalized 2).* Seven sites (Hanford, INEL, LANL, ORR, SRS, PORTS, and RFETS) treat, and 6 sites dispose.
- *Case 15 (Regionalized 4).* Four sites (Hanford, INEL, ORR, and SRS) treat, and 6 sites dispose.
- *Case 17 (Centralized).* One site treats (Hanford), and 1 site disposes.
- *Case 26 (Remote-handled).* Four sites (Hanford, INEL, ORR, and SRS) treat and dispose (RH) and dispose.

Tables F.6.5-F.6.7 summarize the radiological source term parameters and frequency groups for the accidents. Separate incineration facilities were assumed for treating alpha and non-alpha contaminated waste. Detailed radionuclide releases and chemical source terms for accidents are provided Mueller (1995).

Table F.6.4 Summary of WM LLMW Radiological Accidents Analyzed [a]

			Operational Events			External Events		
Function	WM PEIS Alternative[b]	Site[c]	Handling Breaches	Facility Fire	Facility Explosion	Seismic	Large Aircraft	Small Aircraft
Handling	All	Ames	×	–[d]	–	–	–	–
	All	ANL-E	×	–	–	–	–	–
	All	ANL-W	×	–	–	–	–	–
	All	Bettis	×	–	–	–	–	–
	All	BCL	×	–	–	–	–	–
	All	BNL	×	–	–	–	–	–
	All	Charleston	×	–	–	–	–	–
	All	Colonie	×	–	–	–	–	–
	All	ETEC	×	–	–	–	–	–
	All	FEMP	×	–	–	–	–	–
	All	GA	×	–	–	–	–	–
	All	GJPO	×	–	–	–	–	–
	All	Hanford	×	–	–	–	–	–
	All	INEL	×	–	–	–	–	–
	All	ITRI	×	–	–	–	–	–
	All	KAPL-S	×	–	–	–	–	–
	All	KCP	×	–	–	–	–	–
	All	KAPL-K	×	–	–	–	–	–
	All	KAPL-W	×	–	–	–	–	–
	All	LANL	×	–	–	–	–	–
	All	LBL	×	–	–	–	–	–
	All	LEHR	×	–	–	–	–	–
	All	LLNL	×	–	–	–	–	–
	All	Mare Is	×	–	–	–	–	–
	All	Mound	×	–	–	–	–	–
	All	Norfolk	×	–	–	–	–	–
	All	NTS	×	–	–	–	–	–
	All	ORR	×	–	–	–	–	–
	All	PGDP	×	–	–	–	–	–
	All	Pantex	×	–	–	–	–	–
	All	Pearl H	×	–	–	–	–	–
	All	Ports Nav	×	–	–	–	–	–
	All	PORTS	×	–	–	–	–	–
	All	PPPL	×	–	–	–	–	–
	All	Puget So	×	–	–	–	–	–
	All	RFETS	×	–	–	–	–	–
	All	RMI	×	–	–	–	–	–
	All	SNL-NM	×	–	–	–	–	–
	All	SNL-CA	×	–	–	–	–	–
	All	SRS	×	–	–	–	–	–
	All	UofMo	×	–	–	–	–	–
	All	WVDP	×	–	–	–	–	–
Incineration	1	INEL	–	×	×	×	–	–
	1	ORR	–	×	×	×	–	–
	1	SRS	–	×	×	×	–	–
	2	Ames	–	×	×	×	–	–
	2	ANL-E	–	×	×	×	–	–
	2	Bettis	–	×	×	×	–	–
	2	BCL	–	×	×	×	–	–
	2	BNL	–	×	×	×	–	–
	2	Charleston	–	×	×	×	–	–
	2	Colonie	–	×	×	×	–	–
	2	ETEC	–	×	×	×	–	–
	2	FEMP	–	×	×	×	–	–
	2	GA	–	×	×	×	–	–
	2	GJPO	–	×	×	×	–	–
	2	Hanford	–	×	×	×	–	–
	2	INEL	–	×	×	×	–	–
	2	ITRI	–	×	×	×	–	–
	2	KAPL-S	–	×	×	×	–	–
	2	KCP	–	×	×	×	–	–
	2	KAPL-K	–	×	×	×	–	–

Table F.6.4 Summary of WM LLMW Radiological Accidents Analyzed [a]—Continued

Function	WM PEIS Alternative[b]	Site[c]	Operational Events: Handling Breaches	Operational Events: Facility Fire	Operational Events: Facility Explosion	External Events: Seismic	External Events: Large Aircraft	External Events: Small Aircraft
	2	KAPL-W	–	×	×	×	–	–
	2	LANL	–	×	×	×	–	–
	2	LBL	–	×	×	×	–	–
	2	LEHR	–	×	×	×	–	–
	2	LLNL	–	×	×	×	–	–
	2	Mare Is	–	×	×	×	–	–
	2	Norfolk	–	×	×	×	–	–
	2	ORR	–	×	×	×	–	–
	2	PGDP	–	×	×	×	–	–
	2	Pantex	–	×	×	×	–	–
	2	Pearl H	–	×	×	×	–	–
	2	Ports Nav	–	×	×	×	–	–
	2	PORTS	–	×	×	×	–	–
	2	PPPL	–	×	×	×	–	–
	2	Puget So	–	×	×	×	–	–
	2	RMI	–	×	×	×	–	–
	2	SNL-NM	–	×	×	×	–	–
	2	SRS	–	×	×	×	–	–
	4	ETEC	–	×	×	×	–	–
	4	FEMP	–	×	×	×	–	–
	4	Hanford	–	×	×	×	–	–
	4	INEL	–	×	×	×	–	–
	4	LANL	–	×	×	×	–	–
	4	LLNL	–	×	×	×	–	–
	4	ORNL	–	×	×	×	–	–
	4	PGDP	–	×	×	×	–	–
	4	Pantex	–	×	×	×	–	–
	4	PORTS	–	×	×	×	–	–
	4	RFETS	–	×	×	×	–	–
	4	SRS	–	×	×	×	–	–
	7	Hanford	–	×	×	×	–	–
	7	INEL	–	×	×	×	–	–
	7	LANL	–	×	×	×	–	–
	7	ORNL	–	×	×	×	–	–
	7	PORTS	–	×	×	×	–	–
	7	RFETS	–	×	×	×	–	–
	7	SRS	–	×	×	×	–	–
	15	Hanford	–	×	×	×	–	–
	15	INEL	–	×	×	×	–	–
	15	ORR	–	×	×	×	–	–
	15	SRS	–	×	×	×	–	–
	17	Hanford	–	×	×	×	–	–
	26	Hanford	–	×	×	×	–	–
	26	INEL	–	×	×	×	–	–
	26	ORR	–	×	×	×	–	–
	26	SRS	–	×	×	×	–	–
α-Incineration[e]	2	INEL	–	×	×	×	–	–
	2	LANL	–	×	×	×	–	–
	2	LLNL	–	×	×	×	–	–
	2	RFETS	–	×	×	×	–	–
	2	SRS	–	×	×	×	–	–
	4	INEL	–	×	×	×	–	–
	4	LANL	–	×	×	×	–	–
	4	LLNL	–	×	×	×	–	–
	4	RFETS	–	×	×	×	–	–
	4	SRS	–	×	×	×	–	–
	7	INEL	–	×	×	×	–	–
	7	LANL	–	×	×	×	–	–
	7	RFETS	–	×	×	×	–	–
	7	SRS	–	×	×	×	–	–
	15	INEL	–	×	×	×	–	–
	15	SRS	–	×	×	×	–	–
	17	Hanford	–	×	×	×	–	–
	26	INEL	–	×	×	×	–	–

Footnotes on next page

Table F.6.4 Summary of WM LLMW Radiological Accidents Analyzed [a]—Continued

[a] Only one source term, generally corresponding to the risk-dominant sequence for each accident initiator, was selected for transmittal to ORR.

[b] Eight cases are considered for WM LLMW alternatives, including Cases 1, 2, 4, 7, 10, 15, 17 and 26. Case 7 (Regionalized 2: 7 sites treat, 6 sites dispose) and 10 (Regionalized 3: 7 sites treat, 1 site disposes) are equivalent with respect to the risk-dominant treatment technologies and the amount of waste at each site; therefore, only Case 7 was analyzed. All WM PEIS cases are defined in Chapter 2 of the WM PEIS. The WM PEIS cases analyzed are described as follows:

- *Case 1 (No Action)*. Three sites (INEL, ORR, and SRS) treat and store, all remaining sites store.
- *Case 2 (Decentralized)*. Forty-nine sites treat, and 16 sites dispose.
- *Case 4 (Regionalized 1)*. Eleven sites (Hanford, INEL, LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS) treat, and 12 sites dispose.
- *Case 7 (Regionalized 2)*. Seven sites (Hanford, INEL, LANL, ORR, SRS, PORTS, and RFETS) treat, and 6 sites dispose.
- *Case 15 (Regionalized 4)*. Four sites (Hanford, INEL, ORR, and SRS) treat, and 6 sites dispose.
- *Case 17 (Centralized)*. One site treats (Hanford), and 1 site disposes.
- *Case 26 (Remote-handled)*. Four sites (Hanford, INEL, ORR, and SRS) treat and dispose (RH) and dispose.

[c] Abbreviations: Ames = Ames Laboratory; Bettis = Bettis Atomic Power Plant; BCL = Battelle Columbus Laboratories; BNL = Brookhaven National Laboratory; Charleston = Charleston Naval Shipyard; GA = General Atomics; GJPO = Grand Junctions Project Office; ITRI = Inhalations Toxicology Research Institute; KAPL-K = Knolls Atomic Power Laboratory (Kesselring); KAPL-S = Knolls Atomic Power Laboratory (Schenectady); 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; Mound = Mound Plant; Norfolk = Norfolk Naval Shipyard; Pearl H = Pearl Harbor Naval Shipyard; Ports Nav = Portsmouth Naval Shipyard; PPPL = Princeton Plasma Physics Laboratory; Puget So = Puget Sound Naval Shipyard; RMI = Reactive Metals, Inc.; SNL-NM = Sandia National Laboratories (New Mexico); SNL-CA = Sandia National Laboratories (California); and UofMo = University of Missouri.

[d] – = not applicable.

[e] α-incineration refers to incineration of waste categorized as alpha-emitting.

Table F.6.5 Frequencies and Radiological Source Term Parameters for WM LLMW Drum Handling Accidents

WM PEIS Alternative	Site	Accident	Frequency Bin (/yr) > 1E-2	1E-4–1E-2	1E-6–1E-4	< 1E-6	VMAR (m^3)	MAR (Ci)	DF	Total Release (Ci)
All	Ames	Drum handling breach	X	–[a]	–	–	2.0E-01	1.1E-03	0.25	2.4E-07
All	ANL-E	Drum handling breach	X	–	–	–	2.0E-01	1.5E-01	0.25	3.5E-04
All	ANL-W	Drum handling breach	X	–	–	–	2.0E-01	7.3E+00	0.25	1.6E-01
All	BAPL	Drum handling breach	X	–	–	–	2.0E-01	6.1E-01	0.25	3.5E-03
All	Battelle	Drum handling breach	X	–	–	–	2.0E-01	1.1E-03	0.25	5.4E-08
All	BNL	Drum handling breach	X	–	–	–	2.0E-01	1.5E-01	0.25	2.8E-04
All	CNS	Drum handling breach	X	–	–	–	2.0E-01	7.3E+00	0.25	1.5E-01
All	Colonie	Drum handling breach	X	–	–	–	2.0E-01	1.1E-03	0.25	5.0E-08
All	ETEC	Drum handling breach	X	–	–	–	2.0E-01	1.5E-01	0.25	3.7E-04
All	FMEP	Drum handling breach	X	–	–	–	2.0E-01	1.1E-03	0.25	4.5E-07
All	GATOMIC	Drum handling breach	X	–	–	–	2.0E-01	1.1E-03	0.25	2.6E-07
All	GJCT	Drum handling breach	X	–	–	–	2.0E-01	1.1E-03	0.25	1.8E-06
All	HANF	Drum handling breach	X	–	–	–	2.0E-01	6.1E-01	0.25	3.1E-03
All	INEL	Drum handling breach	X	–	–	–	2.0E-01	3.5E+00	0.25	2.9E-02
All	ITRI	Drum handling breach	X	–	–	–	2.0E-01	5.5E-01	0.25	1.3E-01
All	KAPL	Drum handling breach	X	–	–	–	2.0E-01	7.0E+00	0.25	8.2E-02
All	KCP	Drum handling breach	X	–	–	–	2.0E-01	7.3E+00	0.25	1.6E-01
All	KKS	Drum handling breach	X	–	–	–	2.0E-01	7.0E+00	0.25	7.3E-02
All	KWS	Drum handling breach	X	–	–	–	2.0E-01	7.1E+00	0.25	1.1E-01
All	LANL	Drum handling breach	X	–	–	–	2.0E-01	5.4E-01	0.25	1.3E-01
All	LBL	Drum handling breach	X	–	–	–	2.0E-01	1.3E+01	0.25	3.1E+00
All	LERHR	Drum handling breach	X	–	–	–	2.0E-01	1.5E-01	0.25	3.2E-04
All	LLNL	Drum handling breach	X	–	–	–	2.0E-01	1.2E+01	0.25	3.1E+00
All	MINS	Drum handling breach	X	–	–	–	2.0E-01	7.1E+00	0.25	9.4E-02
All	Mound	Drum handling breach	X	–	–	–	2.0E-01	1.3E+01	0.25	3.1E+00
All	NNS	Drum handling breach	X	–	–	–	2.0E-01	7.3E+00	0.25	1.6E-01
All	NTS	Drum handling breach	X	–	–	–	2.0E-01	1.3E+01	0.25	3.1E+00
All	ORNL	Drum handling breach	X	–	–	–	2.0E-01	1.5E-01	0.25	3.0E-04
All	Paducah	Drum handling breach	X	–	–	–	2.0E-01	3.8E-01	0.25	2.5E-05
All	PANT	Drum handling breach	X	–	–	–	2.0E-01	5.3E-01	0.25	1.3E-01
All	PHNS	Drum handling breach	X	–	–	–	2.0E-01	7.3E+00	0.25	1.6E-01
All	PNS	Drum handling breach	X	–	–	–	2.0E-01	7.3E+00	0.25	1.6E-01
All	PORTS	Drum handling breach	X	–	–	–	2.0E-01	2.8E-04	0.25	6.1E-08
All	PPPL	Drum handling breach	X	–	–	–	2.0E-01	1.3E+01	0.25	3.1E+00
All	PSNS	Drum handling breach	X	–	–	–	2.0E-01	7.3E+00	0.25	1.6E-01
All	RFP	Drum handling breach	X	–	–	–	2.0E-01	5.2E-03	0.25	1.8E-06
All	RMI	Drum handling breach	X	–	–	–	2.0E-01	1.1E-03	0.25	3.0E-07

Table F.6.5 Frequencies and Radiological Source Term Parameters for WM LLMW Drum Handling Accidents—Continued

WM PEIS Alternative	Site	Accident	Frequency Bin (/yr)				VMAR (m^3)	MAR (Ci)	DF	Total Release (Ci)
			>1E-2	1E-4–1E-2	1E-6–1E-4	<1E-6				
All	SNLA	Drum handling breach	X	–	–	–	2.0E-01	9.6E-01	0.25	1.1E-01
All	SNLL	Drum handling breach	X	–	–	–	2.0E-01	1.3E+01	0.25	3.1E+00
All	SRS	Drum handling breach	X	–	–	–	2.0E-01	9.2E-01	0.25	1.0E-01
All	UMC	Drum handling breach	X	–	–	–	2.0E-01	5.2E-03	0.25	1.3E-06
All	WVDP	Drum handling breach	X	–	–	–	2.0E-01	6.1E-01	0.25	3.7E-03

[a] – = not applicable.

Table F.6.6 Frequencies and Radiological Source Term Parameters for WM LLMW Non-Alpha Incineration Facility Accidents

WM PEIS Alternative[a]	Site	Accident	Frequency Bin (/yr) >1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	<1.0E-06	Waste Form of MAR	Source Term Parameters VMAR (m^3)	MAR (Ci)	DF	RARF[b]	LPF[b]	Total Release (Ci)
1	INEL	Explosion in the rotary kiln	X	-[c]	-	-	Inorganic particulates	1.2E-01	4.2E+00	1.2E-01	1.0E-01	1.0E-03	5.1E-05
1	INEL	Fire in the baghouse area	-	X	-	-	Inorganic particulates	1.2E-01	4.2E+00	3.0E-02	1.0E-02	1.0E+00	1.3E-03
1	INEL	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	1.2E-01	4.2E+00	2.0E-01	1.0E-01	1.0E+00	8.5E- 2
1	ORR	Explosion in the rotary kiln	X	-	-	-	Inorganic sludge	2.2E+00	4.3E+00	1.2E-01	1.0E-01	1.0E-03	5.1E-05
1	ORR	Fire in the baghouse area	-	X	-	-	Inorganic sludge	2.2E+00	4.3E+00	3.0E-02	1.0E-02	1.0E+00	1.3E-03
1	ORR	Earthquake followed by fire and explosion	-	-	X	-	Inorganic sludge	2.2E-01	4.3E+00	2.0E-01	1.0E-01	1.0E+00	8.6E-02
1	SRS	Incineration ash explosion	X	-	-	-	Halogenated organic liquid	2.5E-01	5.9E+00	1.2E-01	1.0E-01	1.0E-03	7.1E-05
1	SRS	Fire in the baghouse area	-	X	-	-	Halogenated organic liquid	2.5E-01	5.9E+00	3.0E-02	1.0E-02	1.0E+00	1.8E-03
1	SRS	Earthquake followed by fire and explosion	-	-	-	-	Halogenated organic liquid	2.5E-01	5.9E+00	2.0E-01	1.0E-01	1.0E+00	1.2E-01
2	Ames	Explosion in the rotary kiln	X	-	-	-	Solid lab packs	3.3E-05	3.5E-07	1.2E-01	1.0E-01	1.0E-03	4.2E-12
2	Ames	Fire in the baghouse area	-	X	-	-	Solid lab packs	3.3E-05	3.5E-07	3.0E-02	1.0E-02	1.0E+00	1.0E-10
2	Ames	Earthquake followed by fire and explosion	-	-	X	-	Solid lab packs	3.3E-05	3.5E-07	2.0E-01	1.0E-01	1.0E+00	7.0E-09
2	ANL-E	Explosion in the rotary kiln	X	-	-	-	Contaminated soil	8.1E-01	6.2E-01	1.2E-01	1.0E-01	1.0E-03	7.4E-06
2	ANL-E	Fire in the baghouse area	-	X	-	-	Contaminated soil	8.1E-01	6.2E-01	3.0E-02	1.0E-02	1.0E+00	1.9E-04
2	ANL-E	Earthquake followed by fire and explosion	-	-	X	-	Contaminated soil	8.1E-01	6.2E-01	2.0E-01	1.0E-01	1.0E+00	1.2E-02
2	Bettis	Explosion in the rotary kiln	X	-	-	-	Organic particulates	2.5E-04	7.5E-03	1.2E-01	1.0E-01	1.0E-03	8.9E-08
2	Bettis	Fire in the baghouse area	-	X	-	-	Organic particulates	2.5E-04	7.5E-03	3.0E-02	1.0E-02	1.0E+00	2.2E-06
2	Bettis	Earthquake followed by fire and explosion	-	-	X	-	Organic particulates	2.5E-04	7.5E-03	2.0E-01	1.0E-01	1.0E+00	1.5E-04
2	BCL	Explosion in the rotary kiln	X	-	-	-	Organic lab packs	6.3E-06	6.4E-08	1.2E-01	1.0E-01	1.0E-03	7.7E-13
2	BCL	Fire in the baghouse area	-	X	-	-	Organic lab packs	6.3E-06	6.4E-08	3.0E-02	1.0E-02	1.0E+00	1.9E-11
2	BCL	Earthquake followed by fire and explosion	-	-	X	-	Organic lab packs	6.3E 06	6.4E-08	2.0E-01	1.0E-01	1.0E+00	1.3E-09
2	BNL	Explosion in the rotary kiln	X	-	-	-	Inorganic sludge	1.7E-02	3.3E-02	1.2E-01	1.0E-01	1.0E-03	3.9E 07
2	BNL	Fire in the baghouse area	-	X	-	-	Inorganic sludge	1.7E-02	3.3E-02	3.0E-02	1.0E-02	1.0E+00	9.7E-06
2	BNL	Earthquake followed by fire and explosion	-	-	X	-	Inorganic sludge	1.7E-02	3.3E-02	2.0E-01	1.0E-01	1.0E+00	6.5E-04
2	Charleston	Explosion in the rotary kiln	X	-	-	-	Halogenated organic liquid	2.1E-04	6.8E-02	1.2E-01	1.0E-01	1.0E-03	8.2E-07
2	Charleston	Fire in the baghouse area	-	X	-	-	Halogenated organic liquid	2.1E-04	6.8E-02	3.0E-02	1.0E-02	1.0E+00	2.0E-05
2	Charleston	Earthquake followed by fire and explosion	-	-	X	-	Halogenated organic liquid	2.1E-04	6.8E-02	2.0E-01	1.0E-01	1.0E+00	1.4E-03
2	Colonie	Explosion in the rotary kiln	X	-	-	-	Aqueous/nonhalogen organic liquid	2.4E-04	1.5E-05	1.2E-01	1.0E-01	1.0E-03	1.7E-10
2	Colonie	Fire in the baghouse area	-	X	-	-	Aqueous/nonhalogen organic liquid	2.4E-04	1.5E-05	3.0E-02	1.0E-02	1.0E+00	4.4E-09
2	Colonie	Earthquake followed by fire and explosion	-	-	X	-	Aqueous/nonhalogen organic liquid	2.4E-04	1.5E-05	2.0E-01	1.0E-01	1.0E+00	2.9E-07
2	ETEC	Explosion in the rotary kiln	X	-	-	-	Contaminated soil	1.6E-01	1.2E-01	1.2E-01	1.0E-01	1.0E-03	1.5E-06
2	ETEC	Fire in the baghouse area	-	X	-	-	Contaminated soil	1.6E-01	1.2E-01	3.0E-02	1.0E-02	1.0E+00	3.6E 05
2	ETEC	Earthquake followed by fire and explosion	-	-	X	-	Contaminated soil	1.6E-01	1.2E-01	2.0E-01	1.0E-01	1.0E+00	2.4E-03
2	FEMP	Explosion in the rotary kiln	X	-	-	-	Inorganic particulates	1.6E-01	8.5E-04	1.2E-01	1.0E-01	1.0E-03	1.0E-08
2	FEMP	Fire in the baghouse area	-	X	-	-	Inorganic particulates	1.6E-01	8.5E-04	3.0E-02	1.0E-02	1.0E+00	2.6E 07
2	FEMP	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	1.6E-01	8.5E-04	2.0E-01	1.0E-01	1.0E+00	1.7E-05
2	GA	Explosion in the rotary kiln	X	-	-	-	Inorganic particulates	1.0E-03	5.7E-06	1.2E-01	1.0E-01	1.0E-03	6.8E-11
2	GA	Fire in the baghouse area	-	X	-	-	Inorganic particulates	1.0E-03	5.7E-06	3.0E-02	1.0E-02	1.0E+00	1.7E-09
2	GA	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	1.0E-03	5.7E-06	2.0E-01	1.0E-01	1.0E+00	1.1E-07

Table F.6.6 Frequencies and Radiological Source Term Parameters for WM LLMW Non-Alpha Incineration Facility Accidents—Continued

WM PEIS Alternative[a]	Site	Accident	Frequency Bin (/yr) > 1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	< 1.0E-06	Waste Form of MAR	Source Term Parameters VMAR (m^3)	MAR (Ci)	DF	RARF[b]	LPF[b]	Total Release (Ci)
2	GJPO	Explosion in the rotary kiln	X	-	-	-	Contaminated soil < 50% debris	6.8E-05	3.3E-07	1.2E-01	1.0E-01	1.0E 03	4.0E-12
2	GJPO	Fire in the baghouse area	-	X	-	-	Contaminated soil < 50% debris	6.8E-05	3.3E-07	3.0E-02	1.0E-02	1.0E+00	1.0E-10
2	GJPO	Earthquake followed by fire and explosion	-	-	X	-	Contaminated soil < 50% debris	6.8E-05	3.3E-07	2.0E-01	1.0E-01	1.0E+00	6.7E-09
2	Hanford	Explosion in the rotary kiln	X	-	-	-	Contaminated soil < 50% debris	1.6E+00	4.3E+00	1.2E-01	1.0E-01	1.0E-03	5.2E-05
2	Hanford	Fire in the baghouse area	-	X	-	-	Contaminated soil < 50% debris	1.6E+00	4.3E+00	3.0E-02	1.0E-02	1.0E+00	1.3E-03
2	Hanford	Earthquake followed by fire and explosion	-	-	X	-	Contaminated soil < 50% debris	1.6E+00	4.3E+00	2.0E-01	1.0E-01	1.0E+00	8.6E-02
2	INEL	Explosion in the rotary kiln	X	-	-	-	Inorganic particulates	1.3E-01	4.3E+00	1.2E-01	1.0E-01	1.0E-03	5.1E-05
2	INEL	Fire in the baghouse area	-	X	-	-	Inorganic particulates	1.3E-01	4.3E+00	3.0E-02	1.0E-02	1.0E+00	1.3E-03
2	INEL	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	1.3E-01	4.3E+00	2.0E-01	1.0E-01	1.0E+00	8.6E-02
2	ITRI	Explosion in the rotary kiln	X	-	-	-	Aqueous/nonhalogen organic liquid	8.5E-05	6.5E-05	1.2E-01	1.0E-01	1.0E-03	7.9E-10
2	ITRI	Fire in the baghouse area	-	X	-	-	Aqueous/nonhalogen organic liquid	8.5E-05	6.5E-05	3.0E-02	1.0E-02	1.0E+00	2.0E-08
2	ITRI	Earthquake followed by fire and explosion	-	-	X	-	Aqueous/nonhalogen organic liquid	8.5E-05	6.5E-05	2.0E-01	1.0E-01	1.0E+00	1.3E-06
2	KAPL-S	Explosion in the rotary kiln	X	-	-	-	Combustible debris	2.3E 03	3.1E-01	1.2E-01	1.0E-01	1.0E-03	3.7E-06
2	KAPL-S	Fire in the baghouse area	-	X	-	-	Combustible debris	2.3E-03	3.1E-01	3.0E-02	1.0E-02	1.0E+00	9.2E-05
2	KAPL S	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	2.3E-03	3.1E-01	2.0E-01	1.0E-01	1.0E+00	6.1E-03
2	KCP	Explosion in the rotary kiln	X	-	-	-	Combustible debris	9.0E-05	1.2E-02	1.2E-01	1.0E-01	1.0E-03	1.4E-07
2	KCP	Fire in the baghouse area	-	X	-	-	Combustible debris	9.0E-05	1.2E-02	3.0E-02	1.0E-02	1.0E+00	3.6E-06
2	KCP	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	9.0E-05	1.2E-02	2.0E-01	1.0E-01	1.0E+00	2.4E-04
2	KAPL-K	Explosion in the rotary kiln	X	-	-	-	Contaminated soil < 50% debris	6.6E-03	2.0E-01	1.2E-01	1.0E-01	1.0E-03	2.4E-06
2	KAPL-K	Fire in the baghouse area	-	X	-	-	Contaminated soil < 50% debris	6.6E-03	2.0E-01	3.0E-02	1.0E-02	1.0E+00	6.0E-05
2	KAPL-K	Earthquake followed by fire and explosion	-	-	X	-	Contaminated soil < 50% debris	6.6E-03	2.0E-01	2.0E-01	1.0E-01	1.0E+00	4.0E-03
2	KAPL-W	Explosion in the rotary kiln	X	-	-	-	Combustible debris	1.0E-03	1.3E-01	1.2E-01	1.0E-01	1.0E-03	1.6E-06
2	KAPL-W	Fire in the baghouse area	-	X	-	-	Combustible debris	1.0E-03	1.3E-01	3.0E-02	1.0E-02	1.0E+00	4.0E-05
2	KAPL-W	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	1.0E-03	1.3E-01	2.0E-01	1.0E-01	1.0E+00	2.7E-03
2	LANL	Explosion in the rotary kiln	X	-	-	-	Aqueous/nonhalogen organic liquid	5.9E-03	4.5E-03	1.2E-01	1.0E-01	1.0E-03	5.4E-08
2	LANL	Fire in the baghouse area	-	X	-	-	Aqueous/nonhalogen organic liquid	5.9E-03	4.5E-03	3.0E-02	1.0E-02	1.0E+00	1.4E-06
2	LANL	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	4.5E-03	4.6E-02	2.0E-01	1.0E-01	1.0E+00	9.1E-04
4	LLNL	Explosion in the rotary kiln	X	-	-	-	Combustible debris	4.1E-03	4.7E-01	1.2E-01	1.0E-01	1.0E-03	5.7E-06
4	LLNL	Fire in the baghouse area	-	X	-	-	Combustible debris	4.1E-03	4.7E-01	3.0E-02	1.0E-02	1.0E+00	1.4E-04
4	LLNL	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	4.1E-03	4.7E-01	2.0E-01	1.0E-01	1.0E+00	9.5E-03
4	ORR	Explosion in the rotary kiln	X	-	-	-	Inorganic sludge	2.2E+00	4.3E+00	1.2E-01	1.0E-01	1.0E-03	5.1E-05
4	ORR	Fire in the baghouse area	-	X	-	-	Inorganic sludge	2.2E+00	4.3E+00	3.0E-02	1.0E-02	1.0E+00	1.3E-03
4	ORR	Earthquake followed by fire and explosion	-	-	X	-	Inorganic sludge	2.2E+00	4.3E+00	2.0E-01	1.0E-01	1.0E+00	8.6E-02

Table F.6.6 Frequencies and Radiological Source Term Parameters for WM LLMW Non-Alpha Incineration Facility Accidents—Continued

WM PEIS Alternative[a]	Site	Accident	Frequency Bin (/yr) > 1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	< 1.0E-06	Waste Form of MAR	Source Term Parameters VMAR (m^3)	MAR (Ci)	DF	RARF[b]	LPF[b]	Total Release (Ci)
4	PGDP	Explosion in the rotary kiln	X	-	-	-	Halogenated organic liquid	1.3E-02	2.3E-01	1.2E-01	1.0E-01	1.0E-03	2.7E-06
4	PGDP	Fire in the baghouse area	-	X	-	-	Halogenated organic liquid	1.3E-02	2.3E-01	3.0E-02	1.0E-02	1.0E+00	6.9E-05
4	PGDP	Earthquake followed by fire and explosion	-	-	X	-	Halogenated organic liquid	1.3E-02	2.3E-01	2.0E-01	1.0E-01	1.0E+00	4.6E-03
4	Pantex	Explosion in the rotary kiln	X	-	-	-	Combustible debris	8.3E-02	3.4E-02	1.2E-01	1.0E-01	1.0E-03	4.1E-07
4	Pantex	Fire in the baghouse area	-	X	-	-	Combustible debris	8.3E-02	3.4E-02	3.0E-02	1.0E-02	1.0E+00	1.0E-05
4	Pantex	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	8.3E-02	3.4E-02	2.0E-01	1.0E-01	1.0E+00	6.9E-04
4	PORTS	Explosion in the rotary kiln	X	-	-	-	Combustible debris	7.3E-02	4.9E-01	1.2E-01	1.0E-01	1.0E 03	5.8E-06
4	PORTS	Fire in the baghouse area	-	X	-	-	Combustible debris	7.3E-02	4.9E-01	3.0E-02	1.0E-02	1.0E+00	1.5E-04
4	PORTS	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	7.3E-02	4.9E-01	2.0E-01	1.0E-01	1.0E+00	9.7E-03
4	RFETS	Explosion in the rotary kiln	X	-	-	-	Contaminated soil <50% debris	6.8E-05	3.3E-07	1.2E-01	1.0E-01	1.0E-03	4.0E-12
4	RFETS	Fire in the baghouse area	-	X	-	-	Contaminated soil <50% debris	6.8E-05	3.3E-07	3.0E-02	1.0E-02	1.0E+00	1.0E-10
4	RFETS	Earthquake followed by fire and explosion	-	-	X	-	Contaminated soil <50% debris	6.8E-05	3.3E-07	2.0E-01	1.0E-01	1.0E+00	6.7E-09
4	SRS	Explosion in the rotary kiln	X	-	-	-	Halogenated organic liquid	2.5E-01	6.0E+00	1.2E-01	1.0E-01	1.0E-03	7.2E-05
4	SRS	Fire in the baghouse area	-	X	-	-	Halogenated organic liquid	2.5E-01	6.0E+00	3.0E-02	1.0E-02	1.0E+00	1.8E-03
4	SRS	Earthquake followed by fire and explosion	-	-	X	-	Halogenated organic liquid	2.5E-01	6.0E+00	2.0E-01	1.0E-01	1.0E+00	1.2E-01
7	Hanford	Explosion in the rotary kiln	X	-	-	-	Contaminated soil <50% debris	1.6E+00	4.3E+00	1.2E-01	1.0E-01	1.0E-03	5.2E-05
7	Hanford	Fire in the baghouse area	-	X	-	-	Contaminated soil <50% debris	1.6E+00	4.3E+00	3.0E-02	1.0E-02	1.0E+00	1.3E-03
7	Hanford	Earthquake followed by fire and explosion	-	-	X	-	Contaminated soil <50% debris	1.6E+00	4.3E+00	2.0E-01	1.0E-01	1.0E+00	8.6E-02
7	INEL	Explosion in the rotary kiln	X	-	-	-	Inorganic particulates	1.3E-01	4.3E+00	1.2E-01	1.0E-01	1.0E-03	5.1E-05
7	INEL	Fire in the baghouse area	-	X	-	-	Inorganic particulates	1.3E-01	4.3E+00	3.0E-02	1.0E-02	1.0E+00	1.3E-03
7	INEL	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	1.3E-01	4.3E+00	2.0E-01	1.0E-01	1.0E+00	8.6E-02
7	LANL	Explosion in the rotary kiln	X	-	-	-	Combustible debris	8.7E-02	8.0E-02	1.2E-01	1.0E-01	1.0E-03	9.6E-07
7	LANL	Fire in the baghouse area	-	X	-	-	Combustible debris	8.7E-02	8.0E-02	3.0E-02	1.0E-02	1.0E+00	2.4E-05
7	LANL	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	8.7E-02	8.0E-02	2.0E-01	1.0E-01	1.0E+00	1.6E-03
7	ORR	Explosion in the rotary kiln	X	-	-	-	Halogenated organic liquid	3.4E-01	2.5E+00	1.2E-01	1.0E-01	1.0E-03	3.0E-05
7	ORR	Fire in the baghouse area	-	X	-	-	Halogenated organic liquid	3.4E-01	2.5E+00	3.0E-02	1.0E-02	1.0E+00	7.4E-04
7	ORR	Earthquake followed by fire and explosion	-	-	X	-	Halogenated organic liquid	3.4E-01	2.5E+00	2.0E-01	1.0E-01	1.0E+00	4.9E-02
7	PORTS	Explosion in the rotary kiln	X	-	-	-	Contaminated soil	8.2E-01	8.6E-01	1.2E-01	1.0E-01	1.0E-03	1.0E-05
7	PORTS	Fire in the baghouse area	-	X	-	-	Contaminated soil	8.2E 01	8.6E-01	3.0E-02	1.0E-02	1.0E+00	2.6E-04
7	PORTS	Earthquake followed by fire and explosion	-	-	X	-	Contaminated soil	8.2E-01	8.6E-01	2.0E-01	1.0E-01	1.0E+00	1.7E-02
7	RFETS	Explosion in the rotary kiln	X	-	-	-	Combustible debris	9.0E-05	1.2E-02	1.2E-01	1.0E-01	1.0E-03	1.4E-07
7	RFETS	Fire in the baghouse area	-	X	-	-	Combustible debris	9.0E-05	1.2E-02	3.0E-02	1.0E-02	1.0E+00	3.6E-06
7	RFETS	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	9.0E-05	1.2E-02	2.0E-01	1.0E-01	1.0E+00	2.4E-04
7	SRS	Explosion in the rotary kiln	X	-	-	-	Halogenated organic liquid	2.5E-01	6.0E+00	1.2E-01	1.0E-01	1.0E-03	7.2E-05
7	SRS	Fire in the baghouse area	-	X	-	-	Halogenated organic liquid	2.5E-01	6.0E+00	3.0E-02	1.0E-02	1.0E+00	1.8E-03
7	SRS	Earthquake followed by fire and explosion	-	-	X	-	Halogenated organic liquid	2.5E-01	6.0E+00	2.0E-01	1.0E-01	1.0E+00	1.2E-01

Table F.6.6 Frequencies and Radiological Source Term Parameters for WM LLMW Non-Alpha Incineration Facility Accidents—Continued

WM PEIS Alternative[a]	Site	Accident	Frequency Bin (/yr) >1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	<1.0E-06	Waste Form of MAR	Source Term Parameters VMAR (m^3)	MAR (Ci)	DF	RARF[b]	LPF[b]	Total Release (Ci)
15	Hanford	Explosion in the rotary kiln	X	-	-	-	Contaminated soil <50% debris	1.6E+00	4.3E+00	1.2E-01	1.0E-01	1.0E-03	5.2E-05
15	Hanford	Fire in the baghouse area	-	X	-	-	Contaminated soil <50% debris	1.6E+00	4.3E+00	3.0E-02	1.0E-02	1.0E+00	1.3E-03
15	Hanford	Earthquake followed by fire and explosion	-	-	X	-	Contaminated soil <50% debris	1.6E+00	4.3E+00	2.0E-01	1.0E-01	1.0E+00	8.6E-02
15	INEL	Explosion in the rotary kiln	X	-	-	-	Inorganic particulates	1.4E-01	4.3E+00	1.2E-01	1.0E-01	1.0E-03	5.1E-05
15	INEL	Fire in the baghouse area	-	X	-	-	Inorganic particulates	1.4E-01	4.3E+00	3.0E-02	1.0E-02	1.0E+00	1.2E-03
15	INEL	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	1.4E-01	4.3E+00	2.0E-01	1.0E-01	1.0E+00	8.6E-02
15	ORR	Explosion in the rotary kiln	X	-	-	-	Inorganic sludge	2.7E+00	4.7E+00	1.2E-01	1.0E 01	1.0E-03	5.7E-05
15	ORR	Fire in the baghouse area	-	X	-	-	Inorganic sludge	2.7E+00	4.7E+00	3.0E-02	1.0E-02	1.0E+00	1.4E-03
15	ORR	Earthquake followed by fire and explosion	-	-	X	-	Inorganic sludge	2.7E+00	4.7E+00	2.0E-01	1.0E-01	1.0E+00	9.5E-02
15	SRS	Explosion in the rotary kiln	X	-	-	-	Halogenated organic liquid	2.5E-01	6.0E+00	1.2E-01	1.0E-01	1.0E-03	7.2E-05
15	SRS	Fire in the baghouse area	-	X	-	-	Halogenated organic liquid	2.5E-01	6.0E+00	3.0E-02	1.0E-02	1.0E+00	1.8E-03
15	SRS	Earthquake followed by fire and explosion	-	-	X	-	Halogenated organic liquid	2.5E-01	6.0E+00	2.0E 01	1.0E-01	1.0E+00	1.2E-01
17	Hanford	Explosion in the rotary kiln	X	-	-	-	Inorganic sludge	3.5E+00	1.0E+01	1.2E-01	1.0E-01	1.0E-03	1.2E-04
17	Hanford	Fire in the baghouse area	-	X	-	-	Inorganic sludge	3.5E+00	1.0E+01	3.0E-02	1.0E-02	1.0E+00	3.1E-03
17	Hanford	Earthquake followed by fire and explosion	-	-	X	-	Inorganic sludge	3.5E+00	1.0E+01	2.0E-01	1.0E 01	1.0E+00	2.1E-01
26	Hanford	Explosion in the rotary kiln	X	-	-	-	Inorganic particulates	6.5E-05	9.9E-03	1.2E-01	1.0E-01	1.0E-03	1.2E-07
26	Hanford	Fire in the baghouse area	-	X	-	-	Inorganic particulates	6.5E-05	9.9E-03	3.0E-02	1.0E-02	1.0E+00	3.0E-06
26	Hanford	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	6.5E-05	9.9E-03	2.0E-01	1.0E-01	1.0E+00	2.0E-04
26	INEL	Explosion in the rotary kiln	X	-	-	-	Heterogeneous debris	1.9E-01	1.8E+01	1.2E-01	1.0E-01	1.0E-03	2.2E-04
26	INEL	Fire in the baghouse area	-	X	-	-	Heterogeneous debris	1.9E-01	1.8E+01	3.0E-02	1.0E-02	1.0E+00	5.5E-03
26	INEL	Earthquake followed by fire and explosion	-	-	X	-	Heterogeneous debris	1.9E-01	1.8E+01	2.0E-01	1.0E 01	1.0E+00	3.7E-01
26	ORR	Explosion in the rotary kiln	X	-	-	-	Aqueous liquid	1.1E 02	3.0E+00	1.2E-01	1.0E-01	1.0E-03	3.6E-05
26	ORR	Fire in the baghouse area	-	X	-	-	Aqueous liquid	1.1E-02	3.0E+00	3.0E-02	1.0E-02	1.0E+00	9.1E-04
26	ORR	Earthquake followed by fire and explosion	-	-	X	-	Aqueous liquid	1.1E-02	3.0E+00	2.0E-01	1.0E-01	1.0E+00	6.1E-02
26	SRS	Explosion in the rotary kiln	X	-	-	-	Inorganic particulates	7.8E-04	8.3E-02	1.2E-01	1.0E-01	3.0E-03	1.0E-06
26	SRS	Fire in the baghouse area	-	X	-	-	Inorganic particulates	7.8E-04	8.3E-02	3.0E-02	1.0E-02	1.0E+00	2.5E-05
26	SRS	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	7.8E-04	8.3E-02	2.0E-01	1.0E-01	1.0E+00	1.7E-03

[a] The WM PEIS cases analyzed are described as follows:

- *Case 1 (No Action).* Three sites (INEL, ORR, and SRS) treat and store, all remaining sites store.
- *Case 2 (Decentralized).* Forty-nine sites treat, and 16 sites dispose.
- *Case 4 (Regionalized 1).* Eleven sites (Hanford, INEL, LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS) treat, and 12 sites dispose.
- *Case 7 (Regionalized 2).* Seven sites (Hanford, INEL, LANL, ORR, SRS, PORTS, and RFETS) treat, and 6 sites dispose.
- *Case 15 (Regionalized 4).* Four sites (Hanford, INEL, ORR, and SRS) treat, and 6 sites dispose.
- *Case 17 (Centralized).* One site treats (Hanford), and 1 site disposes.
- *Case 26 (Remote-handled).* Four sites (Hanford, INEL, ORR, and SRS) treat and dispose (RH) and dispose.

[b] Values shown are for (nonvolatile) solids such as U-235 or Pu-238; see Appendix D.

[b] "–" = not applicable.

Table F.6.7 Frequencies and Radiological Source Term Parameters for WM LLMW Alpha Incineration Facility Accidents

			Frequency Bin (/yr)					Source Term Parameters					
WM PEIS Alternative[a]	Site	Accident Sequence	>1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	<1.0E-06	Waste Form of MAR	VMAR (m^3)	MAR (Ci)	DF	RARF[b]	LPF[b]	Total Release (Ci)
2	INEL	Explosion in the rotary kiln	X	-[c]	-	-	Combustible debris	1.5E-01	9.3E+00	1.2E-01	1.0E-01	1.0E-03	1.1E-04
2	INEL	Fire in the baghouse area	-	X	-	-	Combustible debris	1.5E-01	9.3E+00	3.0E-02	1.0E-02	1.0E+00	2.8E-03
2	INEL	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	1.5E-01	9.3E+00	2.0E-01	1.0E-01	1.0E+00	1.9E-01
2	LANL	Explosion in the rotary kiln	X	-	-	-	Aqueous/halogen organic liquid	2.9E-02	4.0E-02	1.2E-01	1.0E-01	1.0E-03	4.8E-07
2	LANL	Fire in the baghouse area	-	X	-	-	Aqueous/halogen organic liquid	2.9E-02	4.0E-02	3.0E-02	1.0E-02	1.0E+00	1.2E-05
2	LANL	Earthquake followed by fire and explosion	-	-	X	-	Aqueous/halogen organic liquid	2.9E-02	4.0E-02	2.0E-01	1.0E-01	1.0E+00	8.1E-04
2	LLNL	Explosion in the rotary kiln	X	-	-	-	Aqueous/nonhalogen organic liquid	2.0E-02	1.7E-02	1.2E-01	1.0E-01	1.0E-03	2.0E-07
2	LLNL	Fire in the baghouse area	-	X	-	-	Aqueous/nonhalogen organic liquid	2.0E-02	1.7E-02	3.0E-02	1.0E-02	1.0E+00	5.0E-06
2	LLNL	Earthquake followed by fire and explosion	-	-	X	-	Aqueous/nonhalogen organic liquid	2.0E-02	1.7E-02	2.0E-01	1.0E-01	1.0E+00	3.4E-04
2	RFETS	Explosion in the rotary kiln	X	-	-	-	Aqueous liquid	1.6E-01	1.4E-02	1.2E-01	1.0E-01	1.0E 03	1.7E-07
2	RFETS	Fire in the baghouse area	-	X	-	-	Aqueous liquid	1.6E-01	1.4E-02	3.0E-02	1.0E-02	1.0E+00	4.2E-06
2	RFETS	Earthquake followed by fire and explosion	-	-	X	-	Aqueous liquid	1.6E-01	1.4E-02	2.0E-01	1.0E-01	1.0E+00	2.8E-04
2	SRS	Explosion in the rotary kiln	X	-	-	-	Inorganic particulates	2.1E-01	4.8E-01	1.2E-01	1.0E-01	1.0E-03	5.7E-06
2	SRS	Fire in the baghouse area	-	X	-	-	Inorganic particulates	2.1E-01	4.8E-01	3.0E-02	1.0E-02	1.0E+00	1.4E-04
2	SRS	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	2.1E-01	4.8E-01	2.0E-01	1.0E-01	1.0E+00	9.5E-03
4	INEL	Explosion in the rotary kiln	X	-	-	-	Combustible debris	1.5E-01	9.3E+00	1.2E-01	1.0E-01	1.0E 03	1.1E-04
4	INEL	Fire in the baghouse area	-	X	-	-	Combustible debris	1.5E-01	9.3E+00	3.0E-02	1.0E-02	1.0E+00	2.8E-03
4	INEL	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	1.5E-01	9.3E+00	2.0E-01	1.0E-01	1.0E+00	1.9E-01
4	LANL	Explosion in the rotary kiln	X	-	-	-	Aqueous/halogen organic liquid	2.9E-02	4.0E-02	1.2E-01	1.0E-01	1.0E 03	4.8E-07
4	LANL	Fire in the baghouse area	-	X	-	-	Aqueous/halogen organic liquid	2.9E-02	4.0E-02	3.0E-02	1.0E-02	1.0E+00	1.2E-05
4	LANL	Earthquake followed by fire and explosion	-	-	X	-	Aqueous/halogen organic liquid	2.9E-02	4.0E-02	2.0E-01	1.0E-01	1.0E+00	8.1E-04
4	LLNL	Explosion in the rotary kiln	X	-	-	-	Aqueous/nonhalogen organic liquid	2.0E-02	1.7E-02	1.2E-01	1.0E-01	1.0E 03	2.0E-07
4	LLNL	Fire in the baghouse area	-	X	-	-	Aqueous/nonhalogen organic liquid	2.0E-02	1.7E-02	3.0E 02	1.0E-02	1.0E+00	5.0E-06
4	LLNL	Earthquake followed by fire and explosion	-	-	X	-	Aqueous/nonhalogen organic liquid	2.0E-02	1.7E-02	2.0E-01	1.0E-01	1.0E+00	3.4E-04
4	RFETS	Explosion in the rotary kiln	X	-	-	-	Aqueous liquid	1.6E-01	1.4E-02	1.2E-01	1.0E-01	1.0E-03	1.7E-07
4	RFETS	Fire in the baghouse area	-	X	-	-	Aqueous liquid	1.6E-01	1.4E-02	3.0E-02	1.0E-02	1.0E+00	4.2E-06
4	RFETS	Earthquake followed by fire and explosion	-	-	X	-	Aqueous liquid	1.6E-01	1.4E-02	2.0E 01	1.0E-01	1.0E+00	2.8E-04
4	SRS	Incineration ash explosion	X	-	-	-	Inorganic particulates	2.1E-01	4.8E-01	1.2E-01	1.0E-01	1.0E 03	5.7E-06
4	SRS	Fire in the baghouse area	-	X	-	-	Inorganic particulates	2.1E-01	4.8E-01	3.0E-02	1.0E-02	1.0E+00	1.4E-04
4	SRS	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	2.1E-01	4.8E-01	2.0E-01	1.0E-01	1.0E+00	9.5E-03
7	INEL	Explosion in the rotary kiln	X	-	-	-	Combustible debris	1.5E-01	9.3E+00	1.2E-01	1.0E-01	1.0E 03	1.1E-04
7	INEL	Fire in the baghouse area	-	X	-	-	Combustible debris	1.5E-01	9.3E+00	3.0E-02	1.0E-02	1.0E+00	2.8E-03
7	INEL	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	1.5E-01	9.3E+00	2.0E-01	1.0E-01	1.0E+00	1.9E-01

Table F.6.7 Frequencies and Radiological Source Term Parameters for WM LLMW Alpha Incineration Facility Accidents—Continued

			Frequency Bin (/yr)					Source Term Parameters					
WM PEIS Alternative[a]	Site	Accident Sequence	>1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	<1.0E-06	Waste Form of MAR	VMAR (m^3)	MAR (Ci)	DF	RARF[b]	LPF[b]	Total Release (Ci)
7	LANL	Explosion in the rotary kiln	X	-	-	-	Aqueous/halogen organic liquid	2.9E-02	4.0E-02	1.2E-01	1.0E-01	1.0E-03	4.8E-07
7	LANL	Fire in the baghouse area	-	X	-	-	Aqueous/halogen organic liquid	2.9E-02	4.0E-02	3.0E-02	1.0E-02	1.0E+00	1.2E-05
7	LANL	Earthquake followed by fire and explosion	-	-	X	-	Aqueous/halogen organic liquid	2.9E-02	4.0E-02	2.0E-01	1.0E-01	1.0E+00	8.1E-04
7	RFETS	Fire in the baghouse area	-	X	-	-	Aqueous liquid	1.6E-01	1.4E-02	3.0E-02	1.0E-02	1.0E+00	4.2E-06
7	RFETS	Earthquake followed by fire and explosion	-	-	X	-	Aqueous liquid	1.6E-01	1.4E-02	2.0E-01	1.0E-01	1.0E+00	2.8E-04
7	SRS	Explosion in the rotary kiln	X	-	-	-	Inorganic particulates	2.1E-01	4.8E-01	1.2E-01	1.0E-01	1.0E 03	5.7E-06
7	SRS	Fire in the baghouse area	-	X	-	-	Inorganic particulates	2.1E-01	4.8E-01	3.0E-02	1.0E-02	1.0E+00	1.4E-04
7	SRS	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	2.1E-01	4.8E-01	2.0E-01	1.0E-01	1.0E+00	9.5E-03
15	INEL	Explosion in the rotary kiln	X	-	-	-	Combustible debris	1.5E-01	9.3E+00	1.2E-01	1.0E-01	1.0E-03	1.1E-04
15	INEL	Fire in the baghouse area	-	X	-	-	Combustible debris	1.5E-01	9.3E+00	3.0E-02	1.0E-02	1.0E+00	2.8E-03
15	INEL	Earthquake followed by fire and explosion	-	-	X	-	Combustible debris	1.5E-01	9.3E+00	2.0E-01	1.0E-01	1.0E+00	1.9E-01
15	SRS	Explosion in the rotary kiln	X	-	-	-	Inorganic particulates	2.1E-01	4.8E-01	1.2E-01	1.0E-01	1.0E-03	5.7E-06
15	SRS	Fire in the baghouse area	-	X	-	-	Inorganic particulates	2.1E-01	4.8E-01	3.0E-02	1.0E-02	1.0E+00	1.4E-04
15	SRS	Earthquake followed by fire and explosion	-	-	X	-	Inorganic particulates	2.1E-01	4.8E-01	2.0E-01	1.0E-01	1.0E+00	9.5E-03
17	Hanford	Explosion in the rotary kiln	X	-	-	-	Aqueous liquid	1.6E-01	1.4E-02	1.2E-01	1.0E-01	1.0E-03	1.7E-07
17	Hanford	Fire in the baghouse area	-	X	-	-	Aqueous liquid	1.6E-01	1.4E-02	3.0E-02	1.0E-02	1.0E+00	4.3E-06
17	Hanford	Earthquake followed by fire and explosion	-	-	X	-	Aqueous liquid	1.6E-01	1.4E-02	2.0E-01	1.0E-01	1.0E+00	2.8E-04
26	INEL	Explosion in the rotary kiln	X	-	-	-	Heterogeneous debris	1.4E-04	1.5E-02	1.2E-01	1.0E-01	1.0E-03	1.8E-07
26	INEL	Fire in the baghouse area	-	X	-	-	Heterogeneous debris	1.4E-04	1.5E-02	3.0E-02	1.0E-02	1.0E+00	4.4E-06
26	INEL	Earthquake followed by fire and explosion	-	-	X	-	Heterogeneous debris	1.4E-04	1.5E-02	2.0E-01	1.0E-01	1.0E+00	2.9E-04

[a] The WM PEIS cases analyzed are described as follows:

- *Case 1 (No Action).* Three sites (INEL, ORR, and SRS) treat and store, all remaining sites store.
- *Case 2 (Decentralized).* Forty-nine sites treat, and 16 sites dispose.
- *Case 4 (Regionalized 1).* Eleven sites (Hanford, INEL, LANL, ORR, SRS, PORTS, PGDP, FEMP, LLNL, Pantex, and RFETS) treat, and 12 sites dispose.
- *Case 7 (Regionalized 2).* Seven sites (Hanford, INEL, LANL, ORR, SRS, PORTS, and RFETS) treat, and 6 sites dispose.
- *Case 15 (Regionalized 4).* Four sites (Hanford, INEL, ORR, and SRS) treat, and 6 sites dispose.
- *Case 17 (Centralized).* One site treats (Hanford), and 1 site disposes.
- *Case 26 (Remote-handled).* Four sites (Hanford, INEL, ORR, and SRS) treat and dispose (RH) and dispose

[b] Values shown are for particulate (nonvolatile) solids such as U-235 or Pu-238; see Appendix D.

[c] "–" = not applicable.

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F.7 Hazardous Waste

F.7.1 ALTERNATIVES AND SITES ANALYZED

The WM alternatives in the WM PEIS are summarized in Table F.7–1, with the associated waste treatment categories described in Table F.7–2. Calculational source term results for these alternatives are discussed herein.

F.7.2 RISK-DOMINANT ACCIDENTS AND MODELING ASSUMPTIONS

The analysis herein develops distinct risk-dominant accident sequences and associated source terms for handling accidents, storage facility accidents, and treatment facility accidents. Accident scenarios involving chemical wastes representative of (a) potentially life-threatening health effects and (b) the potential for any adverse health effects were selected. Potential for any adverse effects excluded carcinogenesis. Developing a category for carcinogenic effects alone would lead to accidents of negligible consequences, considering the specific chemicals present in the storage facilities. Consequently, only two categories of accidents were determined. The HW constituents of concern were chosen from the DOT list of poison inhalation hazards (PIHs) and from toxicological analyses (Hartmann et al., 1994). Eleven installations that accept over 90 percent of the HW from the DOE complex were selected as representative of the DOE sites. Inventory data for the selected installations were taken from 1992 DOE HW shipment records. Because information on chemical concentrations is usually not given in HW inventory data, concentrations in industrial-grade products were assumed when modeling the source term from a release.

All accidents were divided into three general categories, each having subcategories and including potentially life-threatening and any-adverse-effects end points:

- Spills resulting in partial vaporization of the waste ("spill only")
- Spills followed by ignition of the waste ("spill plus fire")
- "Other event combinations"

Table F.7-1. Specification of HW Alternatives[a]

Alternative	Action	Hanford	INEL	LLNL	LANL	SNL-NM	Pantex	KCP	ANL-E	Fermi	ORR	SRS	Commercial TSDs
No Action/Decentralized[b]													
10% treated onsite at 2 DOE sites	Treat at 2	-[c]	-	-	-	-	-	-	-	-	T	T	T
90% treated commercially	Dispose	-	-	-	-	-	-	-	-	-	-	-	D[d]
Regionalized 1:													
50% treated onsite at 5 DOE sites	Treat at 5	T	T	-	T	-	-	-	-	-	T	T	T
50% treated/disposed commercially	Dispose	-	-	-	-	-	-	-	-	-	-	-	D
Regionalized 2:													
90% treated onsite at 2 DOE sites	Treat at 2	-	T	-	-	-	-	-	-	-	T	-	T
10% treated/disposed commercially	Dispose	-	-	-	-	-	-	-	-	-	-	-	D

[a] The WM PEIS considers the potential consequences of increased use of onsite facilities for treatment versus reliance on commercial facilities. The existing program (no action alternative) relies heavily on commercial vendors for treatment and disposal of those wastes with organic constituents. This table presents a breakdown of activities at 11 sites for these 3 alternatives. The WM PEIS focuses on waste with organics, and the sites denoted by a single "T" in the table conduct organic destruction; however, these sites are also assumed to conduct any additional treatment necessary to meet LDRs. In addition, although organic destruction is assumed to be a part of the existing program at only 3 locations (LANL, ORR, and SRS), most sites perform some very limited degree of treatment onsite by using 1 or more of the following treatment technologies: fuel blending, fuel burning, solvent recycling, stabilization, deactivation, metal removal and recovery, Hg removal and recovery, aqueous treatment, or recycling.
[b] Most sites conduct (1) onsite treatment or (2) neutralization or deactivation of selected wastestreams (or both).
[c] Not applicable.
[d] D = disposal.

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Table F.7-2. Generic HW Treatment Categories and Descriptions

Treatment Capability	Abbreviation	Description
Organic destruction	ORDST	Destruction of organic liquids and solids by a broad spectrum of thermal and nonthermal technologies. Examples include incineration, vitrification, plasma hearth, molten metal, chemical oxidation, electron beam, and silent discharge plasma. Some of these technologies also apply to the STABL and METRC categories.
Aqueous liquids (wastewater treatment for organics)	WWTOR	Treatment technologies for oxidation of organics contained in predominantly aqueous media. Examples include wet oxidation, catalyzed wet oxidation, and supercritical water oxidation.
Metal removal	METRM	Metal ion and particulate removal from liquids by settling, filtration, precipitation, ion exchange, carbon adsorption, etc.
Stabilization	STABL	All immobilization and microencapsulation technologies (for example, cementation, vitrification, polymer encapsulation).
Metal recovery	METRC	Methods for separation and collection of metals from wastestreams for reuse. Examples include sorting, melting, and decontamination.
Mercury separation	HGSEP	All Hg separation, collection, and immobilization methods. Examples include gravitational, thermal, and chemical techniques to separate Hg for recycling or for immobilization by amalgamation.
Decontamination	DECON	Extractive, mechanical, hydraulic, thermal, and electrochemical techniques used to remove contaminants from substrate materials.
Neutralization	NEUTR	Acid or base additions to neutralize wastestreams.
Deactivation	DEACT	Appropriate technologies to deactivate reactive materials (such as sodium or uranium metal) or cyanides before disposal.

- Spills followed by ignition of the waste and an induced explosion in a waste container ("spill plus fire plus explosion")
- Facility fires resulting in a waste container breach ("fire only")
- Mechanical failure of a compressed gas container resulting in an explosion ("spill and explosion")
- Explosion from exposure of reactive material to air followed by fire ("fire and explosion").

Table F.7–3 lists the representative accidents chosen to serve as surrogates for all risk-dominant sequences. Thirteen accidents involve the release of potentially life-threatening toxic gases. Five accidents (1e through 1g and 2e through 2f) involve the release of materials not considered potentially life-threatening but analyzed for any adverse effects. The development of these accidents took into account the following:

- The proximity of classes of chemicals to each other in the storage facilities
- The typical designs of the storage facilities and the required separation of such groups of chemicals as flammable liquids, acids, caustics, combustibles, oxidizers, etc.
- The 90-day residence limit for RCRA HW in a storage facility.

The accident scenarios include a range of high-probability low-consequence accidents and high-consequence low-probability accidents. In general, the scenarios involve chemical or physical change in stored materials subsequent to an initial incident. Equations were written to represent the changes anticipated to occur during the accidents. Toxic gaseous products were identified and their masses estimated from the mass of the reactants and the stoichiometry of the reactions. The annual frequency of accidents includes both the spill frequency and, where appropriate, the probability that all of the agents are present at the same time. Rates of releases were estimated on the basis of engineering judgment and the recognition that such rates often decay exponentially with time. Obviously, the exact course of an accident is shaped by a multitude of factors, including (but not limited to) temperature, humidity, pooling versus spreading of spills, the exact composition and concentration of reactive materials (often unknown), and the proximity and nature of nearby reactive materials (including packaging, shelving, and flooring). Appendix H in Mueller et al. (1995) provides details on the selection of the accident scenarios, on the chemistry involved in their progress, and on the estimation of the rates of release of the toxic gases.

The probability of an accident depends on the throughput of the waste type or types involved. The subsequent progression of some accident scenarios requires specific additional waste types to be in proximity to the initiating container; for instance, accident subcategory 2d is dependent on the probability that flammable liquids, accelerants, and Hg cells are being stored at the same time.

A release is defined as some form of airborne release in terms of vapor, gas, aerosol, or particulates from the original chemical or the reaction product. Recall that all hazardous chemical releases were placed into one of 18 subcategories, depending on the category of accident (for example, spill or spill plus fire), the range of accidents within the category, and the particular health end point. Many

Table F.7-3. Airborne Release Assumptions for Representative HW Accidents[a]

Scenario	Toxic Gas Released	Mass of Waste Spilled (lb)	Release Rate Functional Form (lb/min)	Annual Frequency (per Container-Handling[b] Operation)	Concentration Limit[c] PAEC Value	Concentration Limit[c] PLC Value
Spill						
(1a) Alkaline waste spill (i.e., NH_4OH) releasing moderately toxic byproducts	NH_3	210 lb of 28% NH_4OH (59 lb)	0-10 min: 3 lb/min; 10-150 min: $3e^{-k_1(t-10)}$, d	2E-04	24.5	560
(1b) Acid waste spill (i.e., HCl) releasing moderately toxic vapor	Hcl	450 lb of 37% HCl (166 lb)	0-10 min: 2 lb/min; 10-600 min: $2e^{-k_2(t-10)}$	2E-04	0.8	100
(1c) Acid waste spill (i.e., HF) releasing highly toxic vapor	HF	30 lb of 50% HF (15 lb)	0-10 min: 2 lb/min; 10-600 min: $2e^{-k_3(t-10)}$	2E-04	1	24
(1d) Fuming acid waste spill (i.e., HNO_3) releasing moderately toxic byproducts	NO_x	30 lb of 70% HNO_3 (21 lb)	0-10 min: 1 lb/min; 10-100 min: $1e^{-k_4(t-10)}$	2E-04	0.41	350
(1e) Acid waste spill (i.e., $C_2H_4O_2$) releasing mildly toxic vapor	$C_2H_4O_2$	30 lb of 100% C_2H_4O2	0-10 min: 0.3 lb/min; 10-900 min: $0.3e^{-k_6(t-10)}$	2E-04	15	NA[e]
(1f) Volatile liquid spill (i.e., CS_2) releasing toxic vapor	CS_2	18 lb of 100% CS_2	0-3 min: 0.5 lb/min; 3-60 min: $0.5e^{-k_7(t-10)}$	2E-04	0.55	NA
(1g) Liquid spill (i.e., 1,1,1-trichloroethane) releasing mildly toxic vapor	1,1,1-trichloroethane	100 lb of 100% 1,1,1-trichloroethane	0-10 min: 40 lb/min	2E-04	31.2	NA
Spill Plus Fire[f]						
(2a) Spill of aromatic hydrocarbon (i.e., BTX) results in burning pool; polyaromatic hydrocarbon (PAH) soot and unburnt hydrocarbon (HC) become airborne	PAH soot and unburnt HC	250 lb of benzene (12% raw, 40% soot, and 48% Co_x)	0-120 min: 2.1 lb/min	2E-05	18.0	3,000
(2b) Spill of flammable liquid (e.g., toluene/acetone), which ignites (with help of $CaCl_2O_2$), and fire spreads to HF container	HF	10 lb of 50% HF (5 lb)	0-1 min: 5 lb/min (puff)	2E-05 probability of HF present	1	24
(2c) Spills and ignition of flammable liquid, engulfing nearby H_2SO_4, KCN, and NaCN containers, releasing only toxic HCN fumes	HCN	40 lb of organic solvents; 20 lb of H_2SO_4; 40 lb of KCN and NaCN	0-1 min: 40 lb/min (puff)	2E-05 probability of KCN present	1 mg/m^3	5 mg/m^3
(2d) Spills and ignition of flammable liquid, accelerated by $Na_2S_2O_8$ and NH_4NO_3, releasing Hg vapor from discarded Hg cells	Hg vapor	2,000 lb of naphtha; 630 lb of oxidizing agent; 50 lb of Hg cells	0-180 min: 2.8 lb/min	2E-05 probability of Hg present	0.01 mg/m^3	0.1 mg/m^3

Table F.7-3. Airborne Release Assumptions for Representative HW Accidents[a]—Continued

Scenario	Toxic Gas Released	Mass of Waste Spilled (lb)	Release Rate Functional Form (lb/min)	Annual Frequency (per Container-Handling[b] Operation)	Concentration Limit[c] PAEC Value	Concentration Limit[c] PLC Value
(2e) Spills and ignition of flammable liquid, breaching nearby containers with Cd-containing compounds (i.e., Cd salts or Ni:Cd batteries)	Cd fumes	300 lb of CdO (17.5 lb of Cd fumes)	0-30 min: 10 lb/min (for fires of 950 °C)	2E-05 probability of Cd present	0.075 ppm	NA
(2f) Spills and ignition of flammable liquid, breaching nearby containers with dichromate salts (i.e., $Na_2Cr_2O_7$ or $K_2Cr_2O_7$)	Dust from burnt and unburnt dichromate salts	30 lb of dichromate dust	1-5 min: 6 lb/min	2E-05 × 1.2E-01 probability of dichromate salt present	0.1 mg/m^3	NA
Other						
(3a) Spills and ignition of flammable liquids; heat from fire causes explosion in compressed gas cylinder, venting NH_3	NH_3	Flammable liquid, 30.5 lb; compressed NH_3	0-5 min: 12 lb/min (puff)	2E-05 × 1E-02 probability of NH_3 present	24.5	560
(3b) Accidental confinement of oxidizing and reducing agents; reaction generates heat, igniting packaging and breaching nearby container	NH_3 or contents of any other nearby gas cylinder	NH_3 (60 lb)	0-5 min: 12 lb/min	3E-03 × probability of both agents present[g]	24.5	560
(3c) Accidental confinement of water with alkali-metal bases or alkali-earth oxides (i.e., Na_2O, K_2O, CaO); reaction generates heat, igniting packaging and breaching nearby containers	NH_3 or any other nearby gas cylinder	NH_3 (60 lb)	0-5 min: 12 lb/min	3E-03 × probability of both agents present[g]	24.5	560
(3d) Accidental rupture of compressed gas (NO_x; flammable) cylinder due to valve failure, releasing toxic gas	NH_3	Compressed gas (100 lb/container)	0-5 min: 100 lb/min	2E-05[h]	24.5	560
(3e) Accidental explosion (without previous spill) of diethyl ether peroxides formed by exposure to air; remaining diethyl ether ignites, spreading to nearby container	NH_3 or contents of any other nearby gas cylinder	Diethyl ether, 2 lb; 210 lb of NH_4OH (60 lb)	0-5 min: 12 lb/min	3E-03[i]	24.5	560

[a] $CaCl_2$ = calcium hypochlorite; CaO = calcium oxide; CdO = cadmium oxide; $C_2H_4O_2$ = acetic acid; CS_2 = carbon disulfide; HCN = hydrogen cyanide; HF = hydrogen fluoride; HNO_3 = nitric acid; H_2SO_4 = sulfuric acid; KCN = potassium cyanide; $Na_2Cr_2O_7$ = sodium dichromate; Na_2O = sodium oxide; $Na_2S_2O_8$ = sodium persulfate; NH_3 = ammonia; NH_4NO_3 = ammonium nitrate; NH_4OH = ammonium hydroxide; and Ni = nickel.
[b] Number of containers at each site varies.
[c] Limits apply for a 15-minute exposure and are in parts per million (ppm) unless otherwise specified. PAEC = potential adverse effect concentration; and PLC = potential life-threatening concentration.
[d] Read as $3 \times \exp[-k(t-10)]$; $k_1 = 0.0145$, $k_2 = 0.0043$, $k_3 = 0.20$, $k_4 = 0.0494$, $k_6 = 0.0111$, and $k_7 = 0.2131$; t = time (min).
[e] NA = not available.
[f] The assumption is that 1 in 10 spills will be ignited by a nearby spark (a conservative value) for an outdoor storage facility. When an accident scenario requires a number of initiating steps, involving more than one type of waste, the probability that all of the necessary constituents would be present at the same time must be included.
[g] The frequency of improper mixing of stored HW containers is approximately 3E-03 (according to Sasser [1992]).
[h] The value for the probability of compressed gas container breach is 1E-04 per container-handling operation; the value for breaching secondary containment is 1E-01.
[i] The frequency of improperly loading a container containing diethyl ether (allowing air to enter the container) is 3E-03 (according to Sasser [1992]).

chemicals in the inventory of each site pose no risk from release and therefore did not need to be considered further. The HW inventories for FY 1992 for 12 DOE sites (the 11 referred to earlier and NTS) were studied to determine the most representative set. Detailed chemical knowledge and engineering judgment were used to assign chemicals to categories. Accident risk during storage is dependent on the number of drums and the average masses of the chemicals placed in each category. Once each accident category was defined, the mass of a released chemical, the elapsed time for release, and the release rates were determined by the use of mass balance equations and consideration of vapor pressure and heat of vaporization at room temperature (Mueller et al. 1995).

F.7.2.1 Packaged Waste Storage and Handling Operations

Hazardous wastes are first accumulated in drums or laboratory packs at the source (laboratory or shop) and then are shipped to a centralized storage facility. Handling accidents during storage or staging operations are expected to dominate the risk of chemical releases to workers because of the frequency of handling and the proximity of the workers. Ignition or explosion of containers due to chemical reactions originating from container-loading errors have also been considered in handling accidents for HW.

F.7.2.1.1 *Material at Risk and Damage Fraction*

Because storage packages are typically plastic-lined, carbon steel 208-L (55-gal) drums, the MAR for handling-accident scenarios is assumed to be one drum. Double containment with an intervening packing of absorbent material is typical of packaged chemically hazardous liquids; however, consistent with previous analyses, the assumption is made that the liquid is completely spilled (that is, DF = 1E+00) upon breach of the waste package (Salazar and Lane, 1992; ORNL, 1993).

F.7.2.1.2 *Spill Scenario Frequencies*

The frequency of container breaches is on the order of 1E–04 per handling operation (see Section F.2). Because HW storage facilities are allowed to hold materials for 90 days as a maximum, all of the containers that arrive at a facility are assumed to be shipped out within 90 days. Two handling operations per container of waste stored at the facility (one loading and one unloading) were assumed.

Consistent with the discussion in Section F.2, the annual frequency for a spill from a container breach for chemical x due to a handling accident can then be given by

$$f_{sx} = 0.0002\, n_x \ , \qquad \text{(F.7–1)}$$

where n_x is the number of waste containers of chemical x received annually at the facility.

F.7.2.1.3 *Spill Plus Fire Scenario Frequencies*

The frequency of occurrence for subcategory 3a (the spill, ignition, and atmospheric release of chemical x) is given by

$$f_{sfx} = f_{sx}\, P_f \ , \qquad \text{(F.7–2)}$$

where P_f is the conditional probability of ignition (1E–01 for outdoor storage pads and 2E–01 for enclosed facilities) (section F.2). The frequency of occurrence in accident subcategories 2b through 2f (the spill and ignition of a flammable chemical, followed by fire propagation and release of chemical y) depends on the concurrent presence of the flammable initiator and the container with the toxic chemical contents:

$$f_{sty} = 0.0002\, n_f\, P_f\, P_{fy} + 0.0002\, n_y\, P_f \ , \qquad \text{(F.7–3)}$$

where n_f is the number of flammable chemical containers, and P_{fy} is the conditional probability that fires involving the flammable chemicals propagate to and ignite the contents of drums containing chemical y. The expression P_{fy} is approximated by the ratio of the number of drums of chemical y to the total number of containers. The second term in the expression is added only if chemical y is also flammable.

F.7.2.1.4 *Frequencies of Other Event Combinations*

Accident subcategory 3a involves a spill and subsequent fire, which then induces an explosion. One SAR (EG&G, 1990) lists a value of 2E–02 for the annual probability of a fire-induced explosion

sufficient to rupture the end walls of a facility. The reference scenario herein assumes the explosion of a compressed gas cylinder engulfed in fire. The frequency is given by

$$f_{sfey} = 0.0002\, n_f P_f P_{fy} P_e \ , \qquad \text{(F.7–4)}$$

where the probability P_{fy} of a drum or cylinders being engulfed is estimated as the approximate fraction of drums containing compressed gas cylinders and where P_e, the conditional probability that the engulfed gas canister will explode, is assumed conservatively to be 1E+00.

Fire-only scenarios 3b and 3c involve the inadvertent mixing of incompatible wastes. Human error probabilities between 1E–03 and 3E–03 are reported (Trusty et al., 1989; Sasser, 1992) for loading or sorting a chemical in the wrong place. Subsequent chemical reactions then generate enough heat to ignite the packaging material with a frequency estimated by

$$f_{frc} = 0.003\, n_{rc} \ , \qquad \text{(F.7–5)}$$

where n_{rc} is the number of containers containing potentially reactive chemical *rc* (or its equivalent) that are received annually at the facility. The surrogate toxic gas assumed to be released during the accident is ammonia (NH_3).

The fire may then spread to other containers and result in a release of toxic chemicals; however, the probability that a reaction among incompatible wastes will generate enough heat to ignite nearby combustible material (that is, paper or cardboard) is expected to be relatively small. The combustible material closest to the containers is usually a cardboard pallet, which requires temperatures of over 232 °C (450 °F) to ignite. Furthermore, the frequency with which containers of toxic waste are stored in proximity to the potential fire needs to be considered. Given the combination of events needed to result in other toxic gas releases, only the NH_3 release is treated herein.

Accident subcategory 3d involves a mechanical breach and subsequent explosion of cylinders of compressed gases. Such cylinders are expected to be stored inside drums, thus providing double-walled storage of the compressed gas. The annual frequency of double-walled container breach per unit handling operation is estimated as 1E–05, implying an order of magnitude credit for the second containment, which is probably conservative, given that conditional breach probabilities after a drop

are estimated at 1E-02. Thus the frequency of a handling accident resulting in an explosion of compressed gas cylinder x is conservatively estimated as

$$f_{secg} = 0.00002\, n_{cg} \ , \qquad \text{(F.7-6)}$$

where n_{cg} is the number of drums with compressed gas containers received annually at the facility.

The spontaneous fire and explosion scenario 3e corresponds to a waste fire and explosion induced by an error in the loading of the waste containers. Some chemicals react violently on contact and must be segregated. The gases produced by such reactions may produce enough pressure inside containers to cause explosions, with resulting container failure. The frequency of this scenario is

$$f_{ferx} = 0.003\, n_{rx} \ , \qquad \text{(F.7-7)}$$

where n_{rx} is the number of containers containing potentially reactive chemical rx (or its equivalent) that are received annually at the facility. The spontaneous formation of peroxides upon exposure of ether to air (and the later ignition of those peroxides) is considered here to be an error in loading. In reality, ether should never be stored for extended periods because of this very problem.

F.7.2.2 Storage Facility Accidents

Hazardous wastes are generally packaged in 208-L (55-gal) drums and stored in RCRA-compliant staging areas or weather protection sheds before offsite shipment for commercial treatment and disposal. A HWSF typically houses over 100 different chemicals, which may include chlorinated solvents, acids, bases, photographic chemicals, ignitable solids and liquids, compressed gases, metal salts, polychlorinated biphenyls, asbestos, and other regulated wastes. Because explosives are generally prohibited, the important hazard characteristics include volatility, flammability, dispersibility, and toxicity. The HW is characterized and segregated on the basis of toxicity, corrosivity, reactivity, and ignitability. Most HWSFs have containment berm areas and individual storage cells that permit waste segregation per RCRA and EPA criteria; some HWSFs have fire detection and suppression capability, and some have forced ventilation. Because of the great diversity of storage facility designs among the DOE sites, a generic facility with segregated storage (Figure F.2-5) was assumed in the analyses.

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A facility-wide fire has been chosen as the representative internal accident. This fire is the type of accident scenario considered as the maximum reasonably foreseeable accident in the INEL HWSF SAR (EG&G, 1990). The fire would engulf a large fraction of the facility, could include secondary explosions and fire propagation from one area to another, and would consume numerous chemicals that vent hazardous substances on combustion or heating.

External events have also been evaluated. The relevant chemicals identified in the operational accidents are assumed to be involved in the facility accident, with the amount of each chemical in facility sequences assumed to be proportional to the numbers of drums that, on average, are present at the facility. A facility fire is the dominant sequence for aircraft impacts; a large spill resulting from numerous breached containers is the dominant sequence for earthquakes.

The chemicals in the facility fire source term are those identified as particularly hazardous in spills with fire (Table F.7–3). The sum of the amounts of these particularly hazardous chemicals defines the MAR, with the release rate and duration for each chemical the same as those for the individual drum fires. The DF is assumed to be 1.0E+00 because the accident scenario assumes no mitigation. In the representative seismic event, the assumption is that 1 percent of the containers fall and break (DF of 1E–02), leading to a large spill of varied chemicals. The externally induced fires (large- and small-aircraft impacts) result in a combined MAR that includes the hazardous releases in a facility-wide fire plus the hazardous releases due to explosions caused by fires or impacts. The representative chemicals in these accidents are shown in Table F.7–3. As in the case of facility fires, the DF for aircraft-induced accidents is taken as 1.0E+00 due to the 90-day limit on storage of RCRA waste.

Conditional probabilities for ignition and fire attendant upon violent breach of packages of flammable liquid are estimated to lie between 1E–01 and 1.0E+00 (ORNL, 1993). An initiating event frequency of 1E–02/yr for a fire involving local propagation is assumed here. A frequency of 1E–02 for failure of the segregation design, the fire suppression systems, or manual procedures is assumed, yielding a resulting facility-wide fire frequency of 1E–04/yr.

The frequencies of the external initiators are dependent on the site, as discussed in Section F.2.6. A conditional probability of container breach of 1.0E+00 has been used for large-airplane impacts and 9E–01 for small-airplane impacts, consistent with the LLW storage facility analysis (LLW and HW are both generally packaged in DOT 208-L [55-gal] drums). For earthquakes, the best estimate (Kennedy and Short, 1990) of the annual frequency of events with a peak ground acceleration exceeding 0.15 g

at the different sites is taken as the frequency of seismic initiation. A ground acceleration of 0.15 g is assumed to be the minimum acceleration required to topple drums in the upper rows of a storage array. A conditional probability of 2E-01 for subsequent drum breach and spill, consistent with the LLW event tree analysis, has been used.

F.7.2.3 Treatment Facility Accidents

Incineration was selected as the most risk-dominant treatment technology for HW. Because SARs for both radioactive waste incinerators and commercial HW incinerators assign a high frequency to kiln explosions, the representative accident is taken to be an explosion that initiates a fire in the waste in the feedstock area. Three externally initiated events (large- and small-aircraft impacts and seismic events) that ignite a feedstock fire are also analyzed. A generic treatment facility, consisting of a series of linked treatment process modules, was described in Section F.2.5.3. A DOE Hazard Category of 2, concomitant performance of its systems, and double HEPA filtration systems were assumed.

The representative source term chemicals are those that were identified as particularly hazardous in case of a fire. The MAR is a fraction of the annual throughput of the incineration facility as established by the WM PEIS alternative. Information from commercial facilities indicates that only a few containers (a few hours' worth of throughput) are kept in the feedstock area. Therefore, 1 percent of the annual throughput was assumed to be in the staging area. This fraction represents the amount of waste in processing and lag storage. The DF depends on the magnitude of the initiator and is assumed to be 1E-01 for internal explosions, 2E-01 for seismic events and small-airplane crashes, and 3E-01 for large-airplane impacts. This accounts for the scattered physical locations of the waste in the treatment facility and the fact that only some of the chemicals in the feedstock area are identified as airborne release hazards in Table F.7-3.

Estimates (discussed in Section F.2.6.3.4) of an annual frequency of 1.5E-02/yr for explosions in the rotary kiln assembly and in the SCC agree with the experience of commercial incineration operators and provide the basis for the internal fire frequencies used herein. The frequencies of aircraft-initiated accidents are dependent on the site. The frequencies were obtained in the same manner as those for the storage facilities. The conditional probabilities of containment and confinement rupture and fire initiation are consistent with those in the LLW accident analysis: 4.5E-01 and 1E-02 for large- and small-airplane crashes, respectively. The annual frequency of a seismic event exceeding the design basis

for a Category 2 facility is 1E-03/yr. As in the LLW facility accident analysis, the conditional probability of rupturing containment and initiating a fire is estimated at 5E-02.

F.7.3 RESULTS

The airborne release parameters for all accident types were shown in Table F.7-3. Table F.7-4 summarizes the estimated frequencies for the different handling accidents in the decentralized, regionalized, and centralized alternatives for each DOE site on the basis of the appropriate surrogate chemical inventories. Single-drum inventories are assumed for the handling accidents.

Tables F.7-5 and F.7-6 summarize the results for the storage and treatment facility accidents by site and alternative. The column labeled "Total Number of Containers" represents the MAR (that is, the total number of containers with the relevant chemicals for each accident that are estimated to be involved in accidents at the facility). The "Number of Containers Breached" is the product of the containers at risk and the DF. The remaining columns in the tables provide the breakdown of the total number of containers involved in the accident for each of the various relevant surrogate chemicals.

Table F.7-4. Site-Dependent Annual Frequencies of Representative HW Handling Accidents

Site	Decentralized Alternative						
Spill[a]	(1a)	(1b)	(1c)	(1d)	(1e)	(1f)	(1g)
ANL-E	1.00E-03	3.00E-03	8.00E-04	6.80E-03	4.00E-04	2.00E-04	1.20E-03
Fermi	0.00E+00	0.00E+00	0.00E+00	8.00E-04	0.00E+00	0.00E+00	2.00E-04
Hanford	1.80E-03	1.00E-03	4.00E-04	7.20E-03	4.00E-04	0.00E+00	3.20E-03
INEL	2.60E-03	5.40E-03	6.00E-04	6.00E-03	0.00E+00	0.00E+00	3.60E-03
KCP	1.60E-03	0.00E+00	0.00E+00	2.00E-04	0.00E+00	0.00E+00	0.00E+00
LLNL	6.40E-03	3.08E-02	4.40E-03	5.84E-02	7.60E-03	4.00E-04	2.26E-02
LANL	3.60E-03	6.20E-03	3.60E-03	4.22E-02	3.60E-03	0.00E+00	7.60E-03
ORR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-03
Pantex	0.00E+00	2.20E-03	4.00E-04	1.22E-02	2.00E-04	0.00E+00	0.00E+00
SNL-NM	4.20E-03	0.00E+00	8.20E-03	2.96E-02	8.00E-04	0.00E+00	6.40E-03
SRS	2.00E-04	0.00E+00	0.00E+00	1.50E-02	1.56E-02	0.00E+00	4.00E-04
Spill Plus Fire[a]	(2a)	(2b)	(2c)	(2d)	(2e)	(2f)	
ANL-E	8.00E-05	7.29E-04	3.19E-04	1.00E-03	1.82E-04	1.37E-04	
Fermi	0.00E+00	6.67E-05	6.67E-05	1.78E-04	0.00E+00	0.00E+00	
Hanford	4.00E-05	7.58E-04	9.48E-05	2.13E-04	1.90E-04	7.11E-05	
INEL	6.00E-05	1.34E-03	7.17E-05	2.15E-04	7.89E-04	2.63E-04	
KCP	0.00E+00	1.80E-03	2.95E-05	5.60E-04	1.18E-04	0.00E+00	
LLNL	4.40E-04	8.09E-03	5.04E-04	1.20E-03	8.16E-04	3.12E-04	
LANL	3.60E-04	3.20E-03	3.45E-04	0.00E+00	5.98E-04	4.37E-04	
ORR	0.00E+00	2.51E-03	0.00E+00	3.81E-05	3.81E-05	0.00E+00	
Pantex	4.00E-05	2.48E-03	5.52E-05	5.52E-04	3.31E-04	0.00E+00	
SNL-NM	8.20E-04	2.74E-03	3.62E-04	3.28E-03	2.31E-03	3.85E-04	
SRS	0.00E+00	7.24E-03	2.78E-05	2.31E-03	2.37E-03	0.00E+00	
Other Event[a]	(3a)	(3b)	(3c)	(3d)	(3e)		
ANL-E	1.39E-05	3.00E-03	9.30E-02	2.80E-04	1.20E-02		
Fermi	0.00E+00	0.00E+00	3.00E-03	1.40E-04	0.00E+00		
Hanford	3.33E-05	3.00E-03	6.60E-02	1.40E-04	1.20E-02		
INEL	5.09E-05	3.00E-03	1.47E-01	1.60E-04	2.70E-02		
KCP	7.57E-05	3.00E-03	9.00E-03	4.40E-04	3.00E-03		
LLNL	1.28E-04	1.20E-02	5.04E-01	6.40E-03	1.02E-01		
LANL	5.39E-05	1.80E-02	8.16E-01	1.48E-03	2.40E-02		
ORR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
Pantex	0.00E+00	3.00E-03	1.02E-01	0.00E+00	3.00E-03		
SNL-NM	5.57E-05	8.40E-02	2.67E-01	1.26E-03	6.90E-02		
SRS	7.84E-06	0.00E+00	2.10E-01	0.00E+00	2.10E-02		

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Table F.7–4. Site-Dependent Annual Frequencies of Representative HW Handling Accidents—Continued

Site	Regionalized Alternative						
Spill[a]	(1a)	(1b)	(1c)	(1d)	(1e)	(1f)	(1g)
Hanford	8.20E-03	3.22E-02	4.80E-03	6.56E-02	8.00E-03	4.00E-04	2.58E-02
INEL	2.60E-03	5.40E-03	6.00E-04	6.00E-03	0.00E+00	0.00E+00	3.60E-03
LANL	7.80E-03	8.40E-03	1.22E-02	8.40E-02	4.60E-03	0.00E+00	1.40E-02
ORR	2.60E-03	3.00E-03	8.00E-04	7.80E-03	4.00E-04	2.00E-04	2.40E-03
SRS	2.00E-04	0.00E+00	0.00E+00	1.50E-02	1.56E-02	0.00E+00	4.00E-04
Spill Plus Fire[a]	(2a)	(2b)	(2c)	(2d)	(2e)	(2f)	
Hanford	4.80E-04	7.38E-03	5.00E-04	1.18E-03	8.40E-04	3.20E-04	
INEL	6.00E-05	1.12E-03	6.00E-05	1.80E-04	6.60E-04	2.20E-04	
LANL	1.22E-03	7.00E-03	6.60E-04	3.30E-03	2.80E-03	7.20E-04	
ORR	8.00E-05	3.24E-03	3.60E-04	1.44E-03	2.60E-04	1.20E-04	
SRS	0.00E+00	5.20E-03	2.00E-05	1.66E-03	1.70E-03	0.00E+00	
Other Event[a]	(3a)	(3b)	(3c)	(3d)	(3e)		
Hanford	7.85E-09	1.50E-02	5.70E-01	6.54E-03	1.14E-01		
INEL	0.00E+00	3.00E-03	1.47E-01	1.60E-04	2.70E-02		
LANL	0.00E+00	1.05E-01	1.19E+00	2.74E-03	9.60E-02		
ORR	7.28E-09	6.00E-03	1.05E-01	8.60E-04	1.50E-02		
SRS	0.00E+00	0.00E+00	2.10E-01	0.00E+00	2.10E-02		
Site	Centralized Alternative						
Spill[a]	(1a)	(1b)	(1c)	(1d)	(1e)	(1f)	(1g)
East	2.80E-03	3.00E-03	8.00E-04	2.28E-02	1.60E-02	2.00E-04	2.80E-03
West	1.86E-02	4.60E-02	1.76E-02	1.56E-01	1.26E-02	4.00E-04	4.34E-02
Spill Plus Fire[a]	(2a)	(2b)	(2c)	(2d)	(2e)	(2f)	
East	8.00E-05	8.44E-03	3.80E-04	3.10E-03	1.96E-03	1.20E-04	
West	1.76E-03	1.55E-02	1.22E-03	4.66E-03	4.31E-03	1.26E-03	
Other Event[a]	(3a)	(3b)	(3c)	(3d)	(3e)		
East	7.41E-09	6.00E-03	3.15E-01	8.60E-04	3.60E-02		
West	3.76E-09	1.23E-01	1.90E+00	9.44E-03	2.37E-01		

[a] Refer to Table F.7-3 for definitions of accidents and released chemicals.

Table F.7-5. Frequencies and Source Term Parameters for WM HW Storage Facility Accidents

WM PEIS Alternative[a]	Site	Accident Frequency (per year)	Total Number of Containers	DF	Total Number of Containers Breached	Representative Subcategory Chemical Containers Involved[b]						
Representative Fire						(2a)	(2b)	(2c)	(2d)	(2e)	(2f)	
1	INEL	1.0E-04	29	1.0E+00	29	14	1	1	2	8	3	
	KCP	1.0E-04	21	1.0E+00	21	15	0	0	5	1	0	
	LLNL	1.0E-04	119	1.0E+00	119	84	6	5	13	8	3	
	LANL	1.0E-04	56	1.0E+00	56	35	5	4	0	7	5	
	ORR	1.0E-04	17	1.0E+00	17	17	0	0	0	0	0	
	Pantex	1.0E-04	33	1.0E+00	33	23	1	1	5	3	0	
	Hanford	1.0E-04	15	1.0E+00	15	8	1	1	2	2	1	
	SNL-NM	1.0E-04	109	1.0E+00	109	30	10	4	36	25	4	
	SRS	1.0E-04	107	1.0E+00	107	65	0	0	21	21	0	
	ANL-E	1.0E-04	28	1.0E+00	28	8	1	4	11	2	2	
	Fermi	1.0E-04	4	1.0E+00	4	1	0	1	2	0	0	
2	INEL	1.0E-04	29	1.0E+00	29	14	1	1	2	8	3	
	Hanford	1.0E-04	94	1.0E+00	94	64	5	4	11	7	3	
	LANL	1.0E-04	151	1.0E+00	151	69	12	7	27	26	8	
	ORR	1.0E-04	52	1.0E+00	52	33	1	3	12	2	1	
	SRS	1.0E-04	107	1.0E+00	107	65	0	0	21	21	0	
3	INEL	1.0E-04	361	1.0E+00	361	194	24	16	58	53	16	
	ORR	1.0E-04	177	1.0E+00	177	106	1	5	39	24	2	
Seismic Events						(1a)	(1b)	(1c)	(1d)	(1e)	(1f)	(1g)
1	INEL	1.8E-04	24	1E-02	0	0	0	0	0	0	0	0
	KCP	6.0E-05	2	1E-02	0	0	0	0	0	0	0	0
	LLNL	1.0E-03	165	1E-02	2	0	1	0	1	0	0	0
	LANL	6.0E-04	86	1E-02	1	0	0	0	1	0	0	0
	ORR	4.0E-04	1	1E-02	0	0	0	0	0	0	0	0
	Pantex	6.0E-05	19	1E-02	0	0	0	0	0	0	0	0
	Hanford	6.0E-05	19	1E-02	0	0	0	0	0	0	0	0
	SNL-NM	6.0E-04	61	1E-02	1	0	0	0	1	0	0	0

Table F.7–5. Frequencies and Source Term Parameters for WM HW Storage Facility Accidents—Continued

WM PEIS Alternative[a]	Site	Accident Frequency (per year)	Total Number of Containers	DF	Total Number of Containers Breached	Representative Subcategory Chemical Containers Involved[b]							
Seismic Events (Cont.)						(1a)	(1b)	(1c)	(1d)	(1e)	(1f)	(1g)	
	SRS	8.0E-05	40	1E-02	0	0	0	0	0	0	0	0	
	ANL-E	1.0E-04	17	1E-02	0	0	0	0	0	0	0	0	
	Fermi	1.0E-04	1	1E-02	0	0	0	0	0	0	0	0	
2	INEL	1.8E-04	24	1E-02	0	0	0	0	0	0	0	0	
	Hanford	6.0E-05	129	1E-02	1	0	0	0	1	0	0	0	
	LANL	6.0E-04	139	1E-02	1	0	0	0	1	0	0	0	
	ORR	4.0E-04	14	1E-02	0	0	0	0	0	0	0	0	
	SRS	8.0E-05	40	1E-02	0	0	0	0	0	0	0	0	
3	INEL	1.8E-04	374	1E-02	4	0	1	0	2	0	0	1	
	ORR	4.0E-04	61	1E-02	1	0	0	0	1	0	0	0	
Large-Aircraft Impacts						(2a)	(2b)	(2c)	(2d)	(2e)	(2f)	(3a)	(3d)
1	INEL	2.0E 09	34	1.0E+00	34	14	1	1	2	8	3	3	2
	KCP	-[c]	29	-	-	-	-	-	-	-	-	-	-
	LLNL	-	207	-	-	-	-	-	-	-	-	-	-
	LANL	-	80	-	-	-	-	-	-	-	-	-	-
	ORR	-	17	-	-	-	-	-	-	-	-	-	-
	Pantex	2.3E-07	33	1.0E+00	33	23	1	1	5	3	0	0	0
	Hanford	8.5E 09	19	1.0E+00	19	8	1	1	2	2	1	2	2
	SNL-NM	2.1E-05	130	1.0E+00	130	30	10	4	36	25	4	5	16
	SRS	8.2E-09	107	1.0E+00	107	65	0	0	21	21	0	0	0
	ANL-E	-	33	-	-	-	-	-	-	-	-	-	-
	Fermi	-	6	-	-	-	-	-	-	-	-	-	-
2	INEL	2.0E-09	34	1.0E+00	34	14	1	1	2	8	3	3	2
	Hanford	8.5E-09	157	1.0E+00	157	64	5	4	11	7	3	7	3
	LANL	-	189	-	-	-	-	-	-	-	-	-	-
	ORR	-	62	-	-	-	-	-	-	-	-	-	-

Table F.7-5. Frequencies and Source Term Parameters for WM HW Storage Facility Accidents—Continued

WM PEIS Alternative[a]	Site	Accident Frequency (per year)	Total Number of Containers	DF	Total Number of Containers Breached	Representative Subcategory Chemical Containers Involved[b]							
Large-Aircraft Impacts (Cont.)						(2a)	(2b)	(2c)	(2d)	(2e)	(2f)	(3a)	(3d)
	SRS	8.2E-09	107	1.0E+00	107	65	0	0	21	21	0	0	0
3	INEL	2.0E-09	503	1.0E+00	503	194	24	16	58	53	16	23	119
	ORR	-	192	-	-	-	-	-	-	-	-	-	-
Small-Aircraft Impacts													
1	INEL	-	34	-	-	-	-	-	-	-	-	-	-
	KCP	2.70E-07	29	1E+00	29	15	0	0	5	1	0	2	6
	LLNL	2.70E-07	207	1E+00	207	84	6	5	13	8	3	8	80
	LANL	2.70E-07	80	1E+00	80	35	5	4	0	7	5	5	19
	ORR	2.70E-07	17	1E+00	17	17	0	0	0	0	0	0	0
	Pantex	-	33	-	-	-	-	-	-	-	-	-	-
	Hanford	-	19	-	-	-	-	-	-	-	-	-	-
	SNL-NM	-	130	-	-	-	-	-	-	-	-	-	-
	SRS	-	107	-	-	-	-	-	-	-	-	-	-
	ANL-E	2.70E-07	33	1E+00	33	8	1	4	11	2	2	1	4
	Fermi	2.70E-07	6	1E+00	6	1	0	1	2	0	0	0	2
2	INEL	-	34	-	-	-	-	-	-	-	-	-	-
	Hanford	-	157	-	-	-	-	-	-	-	-	-	-
	LANL	2.70E-07	189	1E+00	189	71	12	7	27	26	8	8	30
	ORR	2.70E-07	62	1E+00	62	33	1	3	12	2	1	2	8
	SRS	-	107	-	-	-	-	-	-	-	-	-	-
3	INEL	-	503	-	-	-	-	-	-	-	-	-	-
	ORR	2.70E-07	192	1E+00	192	106	1	5	39	24	2	3	12

[a] Case 1 is the No Action/Decentralized alternative with two treatment sites. Case 2 is the Regionalized 1 alternative with five treatment sites. Case 3 is the Regionalized 2 alternative with two treatment sites.
[b] Refer to Table F.7-3 for definitions of released chemicals.
[c] Not applicable.

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Table F.7-6. Frequencies and Source Term Parameters for WM HW Incineration Facility Accidents

WM PEIS Alternative[a]	Site	Accident Frequency (per year)	Total Number of Containers	DF	Number of Containers Breached	Representative Subcategory Chemical Containers Involved[b] 2a	2b	2c	2d	2e	2f
Representative Fire											
2	INEL	1.5E-02	20	1E-01	2	1	0	0	0	1	0
	LANL	1.5E-02	50	1E-01	5	3	0	0	1	1	0
	ORR	1.5E-02	50	1E-01	5	2	1	0	1	1	0
	Hanford	1.5E-02	30	1E-01	3	2	0	0	1	0	0
	SRS	1.5E-02	20	1E-01	2	1	0	0	1	0	0
3	INEL	1.5E-02	80	1E-01	8	5	1	0	1	1	0
	ORR	1.5E-02	80	1E-01	8	5	0	0	2	1	0
Seismic Events											
2	INEL	5.0E-05	20	2E-01	4	2	0	0	0	1	1
	LANL	5.0E-05	50	2E-01	10	7	1	0	1	1	0
	ORR	5.0E-05	50	2E-01	10	5	1	0	2	2	0
	Hanford	5.0E-05	30	2E-01	6	4	0	1	1	0	0
	SRS	5.0E-05	20	2E-01	4	2	0	0	1	1	0
3	INEL	5.0E-05	80	2E-01	16	9	1	1	3	2	0
	ORR	5.0E-05	80	2E-01	16	10	0	1	3	2	0
Large-Aircraft Impacts											
2	INEL	1.2E-09	20	3E-01	6	3	0	0	0	2	1
	LANL	–[c]	–	–	–	–	–	–	–	–	–
	ORR	–	–	–	–	–	–	–	–	–	–
	Hanford	5.4E-09	30	3E-01	9	6	0	1	2	0	0
	SRS	5.0E-09	20	3E-01	6	4	0	0	1	1	0
3	INEL	2.7E-09	80	3E-01	24	12	2	1	4	4	1
	ORR	–	–	–	–	–	–	–	–	–	–
Small-Aircraft Impacts											
2	INEL	–	–	–	–	–	–	–	–	–	–
	LANL	7.0E-09	50	2E-01	10	6	1	1	1	1	0
	ORR	7.0E-09	50	2E-01	10	5	1	0	2	2	0
	Hanford	–	–	–	–	–	–	–	–	–	–
	SRS	–	–	–	–	–	–	–	–	–	–
3	INEL	–	–	–	–	–	–	–	–	–	–
	ORR	7.0E-09	80	2E-01	16	10	0	1	3	2	0

[a] Case 1 is the No Action/Decentralized Alternative with two treatment sites. Case 2 is the Regionalized 1 Alternative with five treatment sites. Case 3 is the Regionalized 2 Alternative with two treatment sites.
[b] Refer to Table F.7-3 for definitions of released chemicals.
[c] Not applicable.

APPENDIX F
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Appendix G

Waste Minimization

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Acronyms and Abbreviations

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

ANL-E	Argonne National Laboratory-East
ANL-W	Argonne National Laboratory-West
BCL	Batelle Columbus Laboratories
BNL	Brookhaven National Laboratory
CH	contact-handled
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
EO	Executive Order
EPCRA	Emergency Planning and Community Right-To-Know Act
ER	environmental restoration
ETEC	Energy Technology Engineering Center
FEMP	Fernald Environmental Management Project
Fermi	Fermi National Accelerator Laboratory
g	gram
GJPO	General Junction Projects Office
h	hour(s)
Hanford	Hanford Site
HW	hazardous waste
INEL	Idaho National Engineering Laboratory
ITRI	Inhalation Toxicology Research Institute
K-25	K-25 Plant, ORR
KAPL-K	Knolls Atomic Power Laboratory (Kesselring)
KAPL-S	Knolls Atomic Power Laboratory (Schenectady)
KAPL-W	Knolls Atomic Power Laboratory (Windsor)
KCP	Kansas City Plant
kg	kilogram(s)
km^2	square kilometer(s)
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory

LDR	land disposal requirements
LEHR	Laboratory for Energy-Related Health Research
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level radioactive waste
m^3	cubic meter(s)
Mare Is	Mare Island Naval Shipyard
MAWS	Minimum Additive Waste Stabilization
mi^2	square mile(s)
Mound	Mound Plant
mrem	millirem(s)
nCi	nanocurie(s)
Norfolk	Norfolk Naval Shipyard
NTS	Nevada Test Site
ORR	Oak Ridge Reservation
Pantex	Pantex Plant
Pearl H	Pearl Harbor Naval Shipyard
PGDP	Paducah Gaseous Diffusion Plant
PORTS	Portsmouth Gaseous Diffusion Plant
Ports Nav	Portsmouth Naval Shipyard
PPOA	pollution prevention opportunity assessment
PPPL	Princeton Plasma Physics Laboratory
Puget So	Puget Sound Naval Shipyard
PWA	process waste assessment
RCRA	Resource Conservation and Recovery Act
R&D	research and development
RDDT&E	Research, Development, Demonstration, Testing, and Evaluation
RFETS	Rocky Flats Environmental Technology Site
RH	remote-handled
RMI	Reactive Metals, Inc.
SNLA	Sandia National Laboratories - Albuquerque
SNL-CA	Sandia National Laboratories - California
SNL-NM	Sandia National Laboratories - New Mexico

SRS	Savannah River Site
TRUW	transuranic waste
TSD	treatment, storage, and disposal
VOCs	volatile organic compounds
WAC	waste acceptance criteria
WIPP	Waste Isolation Plant Project
WM	waste management
WMin/PP	waste minimization and pollution prevention
WM PEIS	Waste Management Prgrammatic Environmental Impact Statement
WVDP	West Valley Demonstration Project
Y-12	Y-12 Plant, ORR
yr	year(s)

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Appendix G
Waste Minimization

G.1 DOE's Waste Minimization and Pollution Prevention Program

The U.S. Department of Energy (DOE) has a Waste Reduction Policy, consistent with Executive Order 12856, that requires DOE installations to engage in waste minimization and pollution prevention (WMin/PP) and to have an established program for implementing this policy. The Office of Waste Management is responsible for coordinating and consolidating the Waste Reduction Policy (DOE, 1994a). The purpose of this appendix is to discuss how DOE's WMin/PP programs and practices may affect the waste loads that waste management (WM) facilities receive, and consequently the need for the facilities. It contains estimates of reductions in waste loads, risks associated with waste management activities, and waste management costs resulting from WMin/PP practices.

The approach used reflects one method of estimating waste minimization impacts in the absence of installation-specific goals for the reduction of wastes and pollution. A 50% reduction in the future generation of waste to be handled in waste management treatment, storage, and disposal (TSD) facilities has been assumed. Cost and risk reductions for the operation of waste management TSD facilities have been calculated based on this assumption. The other factor in cost calculations not yet available is the probable cost of achieving this 50% level of waste generation in the operating facilities that generate the waste. In some instances, such as revamping operations to meet the goal, the cost could be substantial and the net dollar gain through waste minimization would be lower than projected. Since these latter costs cannot yet be calculated, they are considered beyond the scope of this Waste Management Programmatic Environmental Impact Statement (WM PEIS).

Within DOE, WMin/PP are those activities that involve source reduction and recycling of all waste and pollutants, and includes those practices that reduce or eliminate pollutants through increased efficiency in the use of raw materials, energy, water, or other resources, or the protection of natural resources by conservation. Source reduction means any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment prior to recycling, treatment, or disposal; and any practice that reduces the hazards to public health and the environment associated with the release of such substance, pollutants, or contaminants (DOE, 1994b).

WMin/PP programs derive from the Pollution Prevention Act of 1990 (Public Law 101-508, November 5, 1990), which established a national strategy for waste management and pollution control. This strategy places primary reliance on source reduction, followed by environmentally safe recycling, treatment, and disposal. DOE Order 5400.1, "General Environmental Protection Program" (DOE, 1988), requires that DOE facilities develop a WMin/PP plan as part of an environmental protection plan.

On August 3, 1993, President Clinton issued Executive Order (EO) 12856, "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements" (EO, 1993). To help ensure that Federal agencies manage their facilities so that the objectives of the Pollution Prevention Act are met to the maximum extent practicable, EO 12856 requires agencies to develop voluntary goals to reduce their total releases of toxic chemicals or toxic pollutants to the environment and offsite transfers of such toxic chemicals or toxic pollutants by 50% by December 31, 1999.

Subsequent to the issuance of EO 12856, the Secretary of Energy on December 28, 1993, directed that DOE's policy shall be to embrace pollution prevention as the DOE's strategy to reduce the generation of all waste streams and thus minimize the impact of DOE operations on the environment, as well as improving safety of operations and energy efficiencies. The Secretary further directed cognizant Secretarial Offices in DOE to identify, plan, and allocate funds for field implementation of waste minimization and pollution prevention activities during the Departmental budget and review process to provide an identified budget each year dedicated to pollution prevention activities.

On December 27, 1994, the Secretary of Energy approved a Departmental strategy for compliance with EO 12856. In approving the Departmental strategy, the Secretary directed that information on progress made toward meeting the milestones and achieving the goals set forth in strategy are to be included in site pollution prevention awareness plans and in Annual Reports to the Secretary on Waste Generation and Waste Minimization Progress. Specific milestones and goals contained in the approved strategy include:

- By December 31, 1999, achieve a Department-wide 50% reduction of total releases of toxic chemicals to the environment and off-site transfers of such toxic chemicals from the baseline year.

- Establish a Department-wide plan, with goals, to eliminate or reduce unnecessary acquisitions of hazardous substances or toxic chemicals.

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- Establish a Department-wide plan, with goals, to reduce DOE manufacture, process, and use of extremely hazardous substances and toxic chemicals.

- By August 31, 1995, review DOE standards and specifications to identify opportunities to eliminate or reduce unnecessary acquisitions of hazardous or toxic substances, and complete all necessary revisions by December 31, 1998.

In accordance with DOE's policy on pollution prevention, DOE issued the 1994 Waste Minimization/ Pollution Prevention Crosscut Plan (DOE 1994b), which established Department-wide goals to meet the targets of EO 12856. The 1994 crosscut plan, as well as the approved DOE strategy for compliance with EO 12856, calls for each DOE installation to establish installation-specific goals to reduce the generation and use of radioactive materials and other hazardous materials to the extent practicable. The 1994 crosscut plan focuses on wastes and pollutants generated within DOE, and includes an activity plan. The outline of the activity plan, as presented in Table G-1, attempts to fully integrate WMin/PP practices in DOE operations.

DOE's WMin/PP practices in 1991 and 1992 are described in the WMin/PP annual report (DOE, 1993b). Some examples of WMin/PP practices are:

- Substitution of nonhazardous (or less hazardous) for more hazardous solvents. For example, substitution reduced the use of naphtha-based solvents by 90% at the Pantex Plant. Several installations substituted a less harmful material for 1,1,1-trichloroethane.

- Resale to outside manufacturers of virgin chemicals that have exceeded stringent shelf life requirements of the weapons programs.

- Offsite reclamation of lead batteries (lead acid, gel-cells, and nickel-cadmium), waste oil, and photo fixer for silver reclamation.

- Onsite reclamation and recycling of antifreeze, freon, and waste oil.

- Implementation of a chemical exchange program whereby chemicals no longer needed were made available for use by other scientists, who would otherwise buy additional chemicals.

Table G–1. Outline of the WMin/PP Activity Plan

1. WMin/PP Policy Direction Activities	
1.1 Establish Goals to Minimize Waste Generation	Each DOE site will set quantitative WMin/PP goals and implement plans for achieving these goals.
1.2 Establish Senior Management Commitment and Follow-Through for DOE WMin/PP Activities	All DOE and contractor organizations will translate the Secretarial WMin/PP policy into policies specific to their sites or programs and be accountable for incorporating WMin/PP into routine operations.
1.3 Distinguish WMin/PP Budget Allocations through Activity Data Sheets	Specific WMin/PP budgets will be established through preparation of separate Activity Data Sheets.
1.4 Promote Regulatory Review and Reform	The Department will work with regulators and stakeholders to ensure that the best waste management practices are evaluated and incorporated into Federal and State regulations and laws.
1.5 Update DOE Policies, Orders, and Procedures to Integrate WMin/PP	DOE policies, orders, and procedures will be updated to reflect the Department's focus on integrating WMin/PP objectives into all activities.
2. WMin/PP Infrastructure Development	
2.1 Standardize Material and Tracking Systems	The Department will develop standards and criteria to measure materials and wastes and provide performance requirements for materials and waste tracking systems.
2.2 Estimate Waste Management Costs for Use in Decision Making	The Department will develop standards for estimating the costs and benefits of introducing WMin/PP changes into its operations.
2.3 Facilitate WMin/PP Technology Transfer and Information Exchange	The Department will enhance existing systems to optimize WMin/PP technology transfer and information exchange within the DOE complex.
2.4 Develop a DOE Wmin/PP Incentives Program	The Department will acknowledge and reward reductions in waste generation and environmental releases.
2.5 Develop and Conduct WMin/PP Employee Training and Awareness Programs	The Department will operate a comprehensive WMin/PP training program that considers all applicable job-specific situations.
2.6 Develop and Implement a Wmin/PP Outreach and Public Relations Program	The Department will inform government agencies and local communities of WMin/PP accomplishments and invite them to participate in environmental activities and initiatives.
3.1 Develop and Maintain Consistent Sitewide WMin/PP Programs at All Sites	The Department will provide core sitewide WMin/PP activities and services at every site. It will clarify its organizational roles and responsibilities to ensure stable funding and consistent management of its sitewide WMin/PP programs.

Table G-1. Outline of the WMin/PP Activity Plan—Continued

3. WMin/PP Program Implementation	
3.2 Develop and Maintain Consistent Generator-Specific Programs	The Department will require that waste generating organizations include appropriate WMin/PP concepts and techniques into their program operations and other activities such as weapons disassembly, decontamination and decommissioning, and environmental restoration.
3.3 Perform Opportunity Assessment and Identify WMin/PP Projects	The Department, acting to minimize total costs, will perform opportunity assessments and identify and implement WMin/PP projects that show a rapid (within 36 months) return on investment.
3.4 Design WMin/PP into New Products, Processes, and Facilities	The Department will integrate WMin/PP into all new design criteria.
3.5 Integrate WMin/PP into Research, Development, and Demonstration Programs	The Department will couple waste generation and R&D communities to ensure that WMin/PP R&D projects offering the greatest technical benefit are available to generator organizations.
3.6 Modify Procurement Practices to Promote WMin/PP	The Department will promote the purchase of less toxic, more durable, more energy efficient materials.
3.7 Develop Multimedia WMin/PP Strategies	The Department will require that all operations develop and implement engineering design-based pollution and waste prevention strategies, process chemistry and technology strategies, operations-based WMin/PP strategies, and maintenance-based proactive strategies.

Source: Appendix C of DOE (1994b).

- Offsite recycle of freon and methylene chloride resulting in recovery for reuse of approximately 80% of the solvent.

- Replacement of flammable scintillation cocktails with a nonhazardous, biodegradable material that eliminated a mixed waste stream at Brookhaven National Laboratory.

A procedure that may identify WMin/PP opportunities and be a component of a facility's WMin/PP program is the process waste assessment (PWA), also known as a pollution prevention opportunity assessment (PPOA). A PPOA is an analysis of a process or activity to identify opportunities to eliminate or reduce generation of waste or consumption of raw materials, water or energy. Once identified, opportunities are evaluated and compared to determine the most efficient and cost effective option.

G.2 Effect of WMin/PP on Waste Management Activities

Executive Order 12856 requires the Secretary of Energy and the heads of other Federal agencies to ensure that the agency develop voluntary goals to either: reduce the agency's total release of toxic chemicals to the environment and offsite transfers of such toxic chemicals for treatment and disposal by 50%; or to plan for a 50% reduction in the release or offsite transfer of toxic pollutants. The Executive Order defines toxic chemicals to be those chemicals for which toxic chemical release forms shall be completed pursuant to section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 (EPCRA). Toxic pollutants include toxic chemicals. Federal agencies may choose to include other substances such as extremely hazardous chemicals as defined by EPCRA or hazardous wastes as defined under the Resource Conservation and Recovery Act as toxic pollutants.

The 1994 WMin/PP crosscut plan states that installation-specific goals for reduction of wastes and pollution will be set. The Executive Order does not expressly refer to the various waste types; rather, it refers to and defines toxic chemicals and toxic pollutants. The DOE's interpretation of the Executive Order, whether ultimately strict or broad, will influence installation-specific goals. It can be expected that these goals will call for source reductions of at least 50% in the aggregate. Source reduction would be greater than 50% for some waste streams and less than 50% for other waste streams. However, as installation-specific waste minimization plans have not been approved, a simple assumption is made that source reduction will result in a 50% reduction in the annual generation of each waste stream for each year of the time spans considered in the WM PEIS. This is an arbitrary assumption and does not represent the flexibility allowed by DOE policy; however, more precise estimates require the definition of installation-specific goals.

G.2.1 Waste Types Addressed

DOE's WMin/PP program applies to all DOE activities and all types of waste that these activities generate. This appendix emphasizes WMin/PP as it relates to four waste types: (1) low-level radioactive waste (LLW), (2) low-level mixed waste (LLMW), (3) hazardous waste (HW), and (4) transuranic waste (TRUW).

Much of DOE's WMin/PP policy is directed toward source reduction, which affects waste management by reducing the quantity of waste that is transferred to its facilities. Source reduction by generators in Defense Programs, Energy Research, and other DOE offices will affect waste management operations

significantly by reducing the amount and radioactivity level of waste that waste management handles. This could result in fewer shipments of waste and in either TSD facilities with smaller capacities or fewer TSD facilities.

The following sections contain estimates of reductions in the waste loads to TSD facilities, the cost of constructing and operating these facilities, and the human health risks to the public and workers from a 50% reduction in the annual generation of the four waste types. The impact of a given percentage reduction in general depends on the size of the inventory of waste, which cannot be reduced by WMin/PP practices because it already exists. If the inventory is large compared with annual generation, then a reduction in annual generation will have little effect, because most of the waste processed will be from the inventory. On the other hand, if the inventory is small compared with annual generation, a reduction in annual generation will have a greater effect. For the four waste types considered, existing inventories are most significant for TRUW and least significant for HW.

G.2.2 Low-Level Waste

Estimates of the effect of source reduction on LLW facilities are based on information in the LLW technical report (Goyette, 1995), the waste management facility human health risk appendix (Appendix D), and the waste management costs technical report (Sherick and Shropshire, 1995). LLW is divided into 10 waste categories (for example, combustible, surface-contaminated bulk metals and equipment) that define how the waste is treated. Two alternatives with volume reduction treatment (incineration, supercompaction, size reduction, and grout stabilization) are considered here. Regionalized Alternative 2 (Case 9) has volume reduction treatment at 11 installations and disposal at 12 installations; Regionalized Alternative 5 (Case 19) has such treatment at 4 installations and disposal at 6 installations. The waste inventory and annual generation information does not include waste transferred to waste management from environmental restoration (ER) operations.

G.2.2.1 Waste Load Reductions

Estimates of the effect of source reduction are given in Table G-2 for treatment waste loads and in Table G-3 for disposal waste loads. These tables contain waste loads based on current annual generation and waste loads when a 50% decrease in annual generation is assumed. The waste loads are based on the waste

inventory and 20 years of annual generation being treated and disposed of in 10 years. It is assumed, in effect, that the inventory and waste generated for 10 years are stored until the treatment facilities become available during a second 10-year period. This assumption does not apply to aqueous waste and saltstone waste at SRS, which will be treated and disposed of over 20 years. Thus, the treatment and disposal waste loads in Tables G-2 and G-3 are for the second 10-year period. The effect of the first 10 years of operation (for aqueous waste and saltstone at SRS) is mainly on the need for disposal capacity. Existing capacity by technology is also given in these tables so that the effect of WMin/PP practices on the need for new capacity can be assessed.

The waste loads for the WMin/PP cases with a 50% reduction in annual generation are more than 50% of the base cases, that is, a 50% reduction in annual generation rate results in less than a 50% reduction in waste load. This is because the waste loads include existing inventories of waste that are treated along with the new waste. The ratio of inventory to annual generation is dependent on waste category and installation. For simplicity, complex-averaged ratios are used for each waste category. These complexwide waste load reductions are: 42.5% for incineration; 43.4% for solidification; 49.6% for supercompaction; and 37.5% for size reduction. For the four technologies considered, source reduction is estimated to be most effective in reducing waste loads for supercompaction and least effective in reducing waste loads for size reduction. Overall, the total waste load reduction for the four volume reduction technologies is estimated to be approximately 43%. The waste categories contributing to each volume reduction treatment are taken from Goyette (1995).

As Table G-2 shows, a majority of the 11 installations have no existing capacity for volume reduction treatments listed in the table. Except for the Idaho National Engineering Laboratory (INEL), the other DOE installations do not have existing capacities for all the volume reduction technologies considered. Source reduction would reduce the capacities required of new facilities. For the alternatives considered, a source reduction of 50% is estimated to eliminate the need for additional supercompaction capacity at the Hanford Site; for the cases with four regional treatment centers, this source reduction also would eliminate the need for new supercompaction and size reduction capacity at the INEL.

Table G–2. Effect of WMin/PP Source Reduction on Waste Management LLW Treatment Waste Loads (Second 10 Years of Treatment)

Treatment Site	Treatment Technology	Existing Capacity (m^3/yr)	11 Sites (m^3/yr)		4 Sites (m^3/yr)	
			Current	WMin/PP[a]	Current	WMin/PP[a]
FEMP	Incinerate	---	7.7E +02	4.4E+02		
	Solidify	---	3.5E+01	2.0E+01	Not Applicable	Not Applicable
	Supercompact	---	N/A	N/A		
	Size Reduce	---	1.0E+02	6.4E+01		
Hanford	Incinerate	---	5.3	3.0	3.5E+01	2.0E+01
	Solidify	---	5.3E+01	3.0E+01	5.5E+01	3.1E+01
	Supercompact	4.0E+03	4.8E+03	2.4E+03	5.0E+03	2.5E+03
	Size Reduce	---	3.1E+03	2.0E+03	3.2E+03	2.0E+03
INEL	Incinerate	2.2E+03	1.7E+03	1.0E+02	1.0E+04	5.8E+03
	Solidify	2.8E+03	1.0E+03	5.8E+02	1.3E+03	7.4E+02
	Supercompact	5.7E+03	6.8E+02	3.3E+02	5.7E+03	2.9E+03
	Size Reduce	5.0E+03	2.1E+03	1.3E+03	7.1E+03	4.5E+03
LANL	Incinerate	---	5.6E+03	3.2E+03		
	Solidify	---	2.6E+02	1.3E+02	Not Applicable	Not Applicable
	Supercompact	---	4.8E+03	2.7E+03		
	Size Reduce	---	1.1E+03	6.9E+02		
LLNL	Incinerate	---	2.9E+01	1.7E+01		
	Solidify	---	2.1E+02	1.2E+02	Not Applicable	Not Applicable
	Supercompact	1.5E+03	1.2E+02	5.9E+01		
	Size Reduce	1.2E+01	7.5E+01	4.8E+01		
ORR	Incinerate	---	2.4E+02	1.4E+02	3.1E+03	1.8E+03
	Solidify	---	7.9E+02	4.4E+02	9.3E+02	5.3E+02
	Supercompact	1.4E+03	4.4E+03	2.2E+02	5.0E+03	2.5E+03
	Size Reduce	---	1.6E+04	1.0E+04	2.7E+04	1.7E+04
Pantex	Incineration	---	N/A	N/A		
	Solidify	---	1.0	5.7E-01	Not Applicable	Not Applicable
	Supercompact	---	2.6E+02	1.5E+02		
	Size Reduce	---	3.5E+03	2.3E+03		
PORTS	Incineration	---	1.5E+03	8.8E+02		
	Solidify	---	1.3E+02	7.2E+01	Not Applicable	Not Applicable
	Supercompact	---	6.9E+01	3.5E+01		
	Size Reduce	---	1.1E+04	6.9E+03		
PGDP	Incineration	---	5.4E+02	3.1E+02		
	Solidify	---	5.4E+01	3.1E+01	Not Applicable	Not Applicable
	Supercompact	---	5.8E+02	2.9E+02		
	Size Reduce	---	9.4E+01	5.9E+01		

Table G-2. Effect of WMin/PP Source Reduction on Waste Management LLW Treatment Waste Loads (Second 10 Years of Treatment)—Continued

Treatment Site	Treatment Technology	Existing Capacity (m^3/yr)	11 Sites (m^3/yr)		4 Sites (m^3/yr)	
			Current	WMin/PP[a]	Current	WMin/PP[a]
RFETS	Incineration	---	2.8E+03	1.6E+03		
	Solidify	---	2.6E+02	1.5E+02	Not Applicable	Not Applicable
	Supercompact	---	5.9	3.0		
	Size Reduce	---	4.2E+02	2.7E+02		
SRS	Incineration	7.95×10^3	1.5E+03	8.3E+02	1.5E+03	8.3E+02
	Solidify	---	2.0E+03	1.1E+03	2.0E+03	1.1E+03
	Supercompact	2.00×10^4	9.4E+03	4.7E+03	9.4E+03	4.7E+03
	Size Reduce	---	9.2E+02	5.8E+02	9.2E+02	5.8E+02

[a] The WMin/PP source reduction case assumes a 50% reduction in annual generation. When account is taken of the waste inventory to be worked off over 10 years, the waste loads are 57.5%, 56.6%, 50.4%, and 62.5% of the no reduction waste loads for incineration, solidification, supercompaction, and size reduction, respectively.
[b] For ORR and PGDP, the existing solidification capacities are assumed to be adequate to meet the no action waste loads
[c] There are incineration facilities at INEL, ORR, and SRS; these are assumed to be dedicated to treating LLMW and unavailable for LLW.

Table G-3. Effect of WMin/PP Source Reductions on Waste Management LLW Disposal Waste Loads (Second 10 Years of Disposal)

Disposal Site	Existing Disposal Capacity (m^3/yr)	12 Disposal Sites (m^3/yr)		6 Disposal Sites (m^3/yr)	
		Current	WMin/PP[a]	Current	WMin/PP
Hanford	8.5E+03	2.1E+03	1.1E+03	2.1E+03	1.1E+03
INEL	3.9E+03	3.9E+03	2.0E+03	4.7E+03	2.6E+03
NTS	4.5E+04	---[b]	---[b]	6.2E+02	3.2E+02
LANL	1.3E+03	5.1E+03	2.7E+03	6.4E+03	3.5E+03
ORR	6.00	4.9E+03	3.1E+03	2.1E+04	1.2E+04
SRS	5.4E+03	4.5E+04	2.3E+04	4.6E+04	2.3E+04
PORTS	---	1.2E+04	6.3E+03	NA	NA
PGDP	---	4.2E+03	2.1E+03	NA	NA
LLNL	---	6.2E+02	3.1E+02	NA	NA
Pantex	---	7.9E+09	4.9E+02	NA	NA
RFETS	---	1.2E+03	6.3E+02	NA	NA

NA = not a disposal site for this case.
[a] The WMin/PP results are based on a 50% reduction in annual generation. However, the volumes disposed of decreases by less than 50% because the category-dependent inventory is also being disposed of.
[b] In Regionalized Alternative 2, NTS only disposes of its own waste; however, LLW is not generated at NTS.

As indicated in Table G-3, the assumed source reduction from WMin/PP practices affects the adequacy of the existing disposal capacity at INEL. Without the reduction in annual generation, the capacity is inadequate; with an assumed 50% reduction in annual generation, it is adequate. For new disposal sites and some existing disposal sites (Los Alamos National Laboratory [LANL], Oak Ridge Reservation [ORR], and SRS), source reduction would reduce the amount of new capacity needed. For the Hanford Site and the Nevada Test Site (NTS), the existing disposal capacities are adequate regardless of source reduction. Overall, a 50% source is estimated to result in approximately a 48% reduction in disposal waste loads.

G.2.2.2 Cost Savings

Cost savings from WMin/PP source reduction are estimated for treatment, disposal, and transportation. Because installation-specific WMin/PP goals are as yet unavailable, it is assumed that WMin/PP practices reduce new source generation by the same percentage (50%) throughout the DOE complex. There may be additional costs to waste generators to effect such source reductions; however, the costs of making source reductions are beyond the scope of this WM PEIS. The savings from source reduction considered here are the waste management cost savings, which may be higher than the net savings.

Waste management cost savings associated with treatment, disposal, and transportation are considered. These are based on planning-level life-cycle costs for 10 years of operations (see Sherick and Shropshire, 1995). Facility costs for treatment and disposal can be considered to consist of costs related to operations and costs related to construction. Operations costs are assumed to be proportional to throughput (waste load). Cost savings for construction depends on whether there are existing facilities for the type of treatment at an installation. If there are no existing facilities, then costs for construction are assumed to be proportional to waste load. If there are existing facilities, then costs for construction are assumed to be proportional to the difference between the existing capacity and the capacity needed to process (or dispose of) the waste load. A given percentage reduction in waste load results in a greater percentage decrease in capacity needed when there is existing capacity. For example, if existing capacity is half the capacity needed to treat a given waste load, a reduction of 40% in waste load will result in an 80% reduction in the need for new capacity. In general, if the existing waste load is equivalent to E; the fractional decrease in waste loads with waste minimization is equivalent to F; the additional capacity needed without waste

minimization is equivalent to Δ; and Δ_{WMin} is the additional capacity needed with waste minimization, then the fractional new capacity needed is:

$$\Delta_{WMin}/\Delta = (1\text{-}F) - F \times E/\Delta \qquad (1)$$

Cost savings have been estimated for the two volume reduction cases considered above. Estimates of cost savings for treatment at the installations with volume reduction facilities are presented in Table G-4. The treatment costs considered are for incineration, grout stabilization, supercompaction, size reduction (that is, shredding and compacting), packaging, and certification and shipping. More detailed tables showing costs for operations and constructions separately, by treatment module and installation, are given in the attachment to this appendix. The tables in the attachment are for disposal as well as for treatment. The same percentage decreases in costs (F) for incineration, grout stabilization, size reduction, and supercompaction are used as percentage decreases in waste load (see Table G-2). The percentage decreases in costs for packaging and certification and shipping are taken to be the cost-weighted average for incineration, grout stabilization, supercompaction, and size reduction. When there is an existing facility, the complement of Δ_{WMin}/Δ from equation (1) is used for the fractional decrease in construction costs. If equation (1) is negative, then the existing capacity is adequate for the assumed decrease in annual generation rate.

The tables in the attachment of this appendix show the minimum percentage reduction in annual generation at which existing capacity becomes inadequate when existing capacity is adequate for a 50% source reduction. For example, for a source reduction of less than 26%, existing supercompaction capacity at the Hanford Site becomes inadequate; for a source reduction of less than 10%, the existing supercompaction capacity at INEL becomes inadequate; and for a source reduction of less than 37%, the existing size reduction capacity at INEL becomes inadequate. From Table G-4, overall, a 50% source reduction is estimated to result in approximately a 40% reduction in costs for treatment.

Table G–4. Effect of WMin/PP Source Reductions on Costs of Waste Management LLW Treatment[a] for Two Volume Reduction Alternatives (in dollars)

Installation	11 Treatment Sites		4 Treatment Sites	
	100%	WMin/PP[b]	100%	WMin/PP
FEMP	2.57E+08	1.51E+08	—	—
Hanford	8.48E+08	5.19E+08	8.58E+08	5.25E+08
INEL	4.88E+08	2.79E+08	1.48E+09	8.43E+08
LANL	5.50E+08	3.26E+08	—	—
LLNL	1.01E+08	5.75E+07	—	—
ORR	2.39E+09	1.51E+09	2.85E+09	1.78E+09
PGDP	3.74E+08	2.22E+08	—	—
Pantex	5.86E+08	3.68E+08	—	—
PORTS	4.57E+08	2.85E+08	—	—
RFETS	4.90E+08	2.90E+08	—	—
SRS	9.60E+08	5.42E+08	1.26E+09	7.42E+08
Total	7.50E+09	4.55E+09	6.45E+09	3.89E+09

[a] Treatments considered are: incineration, grout stabilization, supercompaction, size reduction (i.e., shredding and compaction), packaging, and certification and shipment.
[b] A 50% reduction annual generation rate is assumed. Costs for operations are assumed to be proportional to throughput. Cost reductions for construction depends on whether there are existing facilities or not. If there are no existing facilities, costs for construction are assumed to be proportional to throughput. If there are existing facilities, cost for construction are proportional to the capacity of new construction needed.

Estimates of cost savings for disposal for an assumed 50% reduction in annual generation of LLW are given in Table G–5 for the alternatives being considered. Percentage cost reductions for disposal are assumed to be equal to percentage waste load reductions for disposal for operations and for construction when there is no existing disposal facility. When there is an existing facility, then the complement of equation (1) is used. Overall, a 50% source reduction is estimated to result in approximately a 48% reduction in disposal costs.

The waste management costs technical report (Sherick and Shropshire, 1995) also contains estimates of transportation costs of LLW for the two volume reduction cases being considered. From the volume information in (Goyette, 1995), percentage waste load reductions by generating installation for a 50% reduction in annual LLW generation were calculated by volume-averaging over waste categories. These generating-site percentage load reductions were multiplied by the transportation costs from each site to yield an estimate of the reduction in transportation costs from a 50% reduction in annual generation. Thus, this estimate is based on the assumption that the cost of transporting waste is proportional to the volume of waste moved and that all transport is from the generation site. Table G–6 contains the estimate of the

total savings in transportation and the total savings for treatment and disposal from the information in Tables G-4 and G-5, respectively. Overall cost reductions for treatment, disposal, and transportation are estimated to be approximately 45% for a 50% source reduction.

The total savings are in the range of $8 to $9 billion for 10 years of operations. These values are for a 20-year interval (inventory and 20 years of waste generation are treated and disposed of in 10 years) and are approximately $400 million per year. This estimate of savings is consistent with a recent estimate of avoidable DOE waste management costs (Teclaw et al., 1993), which estimated avoidable annual costs for LLW of between $10 million and $10 billion.

Table G-5. Effect of WMin/PP Source Reductions on Costs for Waste Management LLW Disposal in Two Volume Reduction Alternatives (in dollars)

Installation	12 Disposal Sites		6 Disposal Sites	
	Current	WMin/PP	Current	WMin/PP
Hanford	3.6E+09	1.9E+09	3.6E+09	2.0E+09
INEL	4.2E+08	2.2E+08	6.2E+08	3.1E+08
LANL	6.0E+08	3.1E+08	5.5E+08	3.0E+08
LLNL	3.1E+08	1.6E+08	NA	NA
NTS	---[a]	---	2.1E+08	1.1E+08
ORR	3.3E+08	2.1E+08	8.0E+08	4.3E+08
PGDP	3.1E+08	1.6E+08	NA	NA
Pantex	2.2E+08	1.4E+08	NA	NA
PORTS	5.2E+08	2.7E+08	NA	NA
RFETS	3.5E+08	1.8E+08	NA	NA
SRS	3.4E+09	1.6E+09	3.4E+09	3.4E+09
Total	1.0E+10	5.2E+09	9.2E+09	4.8E+09

NA = not a disposal site in this case.
[a] In Regionalized Alternative 2, NTS only disposes of its own waste; however, LLW is not generated at NTS.

Table G-6. Summary of Effect of WMin/PP Source Reduction on Costs for Waste Management LLW Waste Management in Two Volume Reduction Alternatives (in dollars)

	11 Treatment, 12 Disposal Sites		4 Treatment, 6 Disposal Sites	
	Current	WMin/PP	Current	WMin/PP
Treatment	7.5E+09	4.6E+09	6.4E+09	3.9E+09
Disposal	1.0E+10	5.2E+09	9.2E+09	4.8E+09
Transportation	6.4E+07	3.3E+07	3.3E+08	2.1E+08

[a] Costs are life cycle costs for treatment at regional treatment facilities, disposal, and all transportation.

G.2.2.3 Human Health Risk Reduction

For the volume reduction cases considered above, reductions in human health risk from source reduction are estimated for routine operations at the volume-reduction treatment centers and disposal sites. Incidence of cancer is taken as the measure of human risk because it applies to the four waste types considered in this appendix (person-rem would apply to LLW, LLMW, and TRUW, but not to HW). Cancer incidence based on the risk from the second 10 years of treatment and storage, not risks per year of operations, were obtained from tables in the human health risk appendix (Appendix D).

Table G-7 contains estimates of the effect of a 50% across-the-board source reduction on cancer incidence among the offsite population and TSD facility workers at installations with volume-reduction facilities. The alternatives considered have either 11 or 4 installations with volume reduction facilities. The radiological risk to the offsite population at the installations with volume reduction facilities arises mainly from releases from incineration facilities. Thus, the effect of source reduction is estimated on the basis of inventory and annual generation (with and without source reduction) of waste in the two LLW categories (combustible, compactable solids; organic liquids) that feed a specific incineration facility. There is an exception for the Pantex Plant volume reduction center, which does not treat the waste categories undergoing incineration. At the Pantex Plant, the health risk to the offsite population is assumed to arise from size-reduction treatment. The human health risk to workers is more evenly distributed among treatment facilities, with the risk being greatest at handling facilities where all waste categories are handled. Therefore, the effect of source reduction is estimated on the basis of the ratio of inventory to annual generation for all waste categories for the LLW treated at a volume-reduction installation. From Table G-7, a 50% source

reduction is estimated to result in approximately a 46% reduction in cancer incidence to both the general public and workers at treatment facilities.

Table G-8 contains estimates of the effects of a 50% across-the-board source reduction on human health risk at disposal facilities. Here, the assumed population consists of farm families that are at risk through the groundwater pathway. (The primary contributor to this risk is carbon-14 because of its long half-life and its leachability characteristics.) The percentage reduction in risk at an installation from source reduction to these farm families is taken to be the same as the reduction in disposal waste load in Table G-3. Overall, a 50% source reduction is estimated to result in a 49% human health risk reduction to farm families.

Table G-7. Effect of WMin/PP Source Reduction On Health Risks from Waste Management LLW Treatment (Cancer Incidence Among the Offsite Population and TSD Workers for Second 10 Years of Treatment)

Site	Receptor	11 Treatment Sites[a]		4 Treatment Sites[b]	
		Current	WMin/PP	Current	WMin/PP
Fernald	Population[c]	7.9E-01	4.3E-01	NA	NA
	Worker[d]	2.3E-02	1.2E-02		
Hanford	Population	1.2E-05	6.0E-06	1.6E-01	8.6E-02
	Worker	6.9E-01	3.5E-01	7.2E-01	3.6E-01
INEL	Population	4.6E-06	2.5E-06	1.4E-03	7.6E-04
	Worker	5.8E-01	3.0E-01	1.9	1.2
LANL	Population	2.7E-02	1.4E-02	NA	NA
	Worker	6.5E-01	3.4E-01		
LLNL	Population	1.3	7.0E-01	NA	NA
	Worker	1.7E-01	1.2E-01		
ORR	Population	5.1E-05	4.6E-05	1.6E-01	9.5E-02
	Worker	4.6E-01	2.8E-01	5.6E-01	1.6E-01
PGDP	Population	6.4E-06	4.2E-06	NA	NA
	Worker	5.8E-03	3.2E-03		
Pantex	Population	3.7E-07	3.5E-07	NA	NA
	Worker	9.5E-03	8.8E-03		

Table G–7. Effect of WMin/PP Source Reduction On Health Risks from Waste Management LLW Treatment (Cancer Incidence Among the Offsite Population and TSD Workers for Second 10 Years of Treatment)—Continued

Site	Receptor	11 Treatment Sites[a]		4 Treatment Sites[b]	
		Current	WMin/PP	Current	WMin/PP
PORTS	Population	1.8E-04	9.8E-05	NA	NA
	Worker	9.6E-02	4.9E-02		
RFETS	Population	6.3E-04	3.3E-04	NA	NA
	Worker	4.0E-03	2.1E-03		
SRS	Population	2.1E-03	1.8E-03	2.1E-03	1.8E-03
	Worker	9.6E-01	4.8E-01	9.6E-01	4.8E-01

NA = not a volume-reduction treatment center for this case.
[a] For Regionalized Alternative 2, a volume-reduction case with 12 disposal sites.
[b] For Regionalized Alternative 5, a volume-reduction case with 6 disposal sites.
[c] Risk to the offsite population is assumed to arise predominantly from releases from incineration. The reduction in risk from a 50% source reduction is estimated on the basis on site-specific inventories and annual generation rates for the waste categories that are treated by incineration (Categories 1 and 9). At the Pantex Plant, which does not have incineration, reduction in risk is based on size reduction treatment of waste categories 3 and 4.
[d] Risk to workers is relatively evenly distributed among treatments; site-specific inventories and annual generation averaged over all waste categories for the sites of origin are used to estimate the reduction in risk to workers from a 50% source reduction.

Table G–8. Effect of WMin/PP Source Reduction on Health Risk from Waste Management LLW Disposal (Cancer Incidence among All Farm Family Generations For Second 10 Years of Disposal)

Disposal Site	12 Disposal Sites[a]		Six Disposal Sites[b]	
	Current	WMin/PP	Current	WMin/PP
Hanford	5.6E-01	3.1E-01	1.2	6.6E-01
INEL	3.0E-06	1.5E-06	2.2E-05	1.1E-05
NTS	—[d]	—[d]	2.9E-03	1.5E-03
LANL	6.5E-03	3.4E-03	5.4E-03	3.0E-03
ORR	2.4E-05	1.5E-05	5.6E-05	3.5E-05
SRS	6.8E-01	3.4E-01	6.8E-01	3.4E-01
PORTS	1.0E-03	5.1E-04	NA	NA
PGDP	1.1E-03	5.6E-04	NA	NA
LLNL	2.5E-03	1.3E-03	NA	NA
Pantex	0	0	NA	NA
RFP	4.5E-02	2.3E-02	NA	NA

NA = not a disposal site.
[a] Regionalized Alternative 2 has 12 disposal sites.
[b] Regionalized Alternative 5 has 6 disposal sites.
[c] The WMin/PP results are based on a 50% reduction in annual generation. However, the volumes disposed of decreases by less than 50% because the category-dependent inventory is also being disposed of.
[d] In Regionalized Alternative 2, NTS only disposes of its own waste; however, LLW is not generated at NTS.

G.2.3 Low-Level Mixed Waste

LLMW is waste that contains both radioactive material and hazardous material. Thus LLMW should be processed so that the hazardous constituents can be treated in accordance with the requirements of the Resource Conservation and Recovery Act (RCRA) and the radioactive components are treated for safe disposal. LLMW may be classified as either contact-handled (CH: dose at waste surface <200 mrem/hr) or remote-handled (RH: dose at waste surface >200 mrem/hr); and also as either alpha LLMW (combined activity of transuranic radionuclides between 10 and 100 nCi/g), or non-alpha LLMW (combined activity of transuranic radionuclides <10 nCi/g). The technologies appropriate for treatment of LLW depend on the physical and chemical properties of the waste. In contrast, technologies appropriate for treatment of LLMW depend on both the physical and chemical properties of the waste, and on the RCRA contaminant category of the hazardous constituents. Only general categories of RCRA contaminants frequent in DOE waste have been considered. These are toxic organics, toxic metals, mercury, ignitables, corrosives, reactives, and combinations thereof. LLMW may require treatment by several technologies in series.

Estimates of the effect of a 50% source reduction have been made for three diverse alternatives for LLMW generated from waste management operations (WM LLMW). These are the Decentralized Alternative with disposal of CH LLMW at 16 sites (Case 2a), Regionalized Alternative 2 with treatment of CH non-alpha LLMW at 7 sites and disposal at 6 sites (Case 7), and the Centralized Alternative with all CH treatment and disposal at one site, the Hanford Site (Case 17). Estimates of the effect of this source reduction are based on information in the LLMW technical report (Wilkins et al., 1995); Appendix D, Waste Management Facility Human Health Risk; and the waste management costs technical report (Sherick and Shropshire, 1995).

G.2.3.1 Waste Load Reductions

Estimates on annual treatment waste load of the effect of a 50% step decrease in generation of WM LLMW are given in Tables G-9 and G-10 for CH non-alpha LLMW and CH alpha LLMW, respectively. The waste loads without the WMin/PP source reduction (the columns labeled "Current") are from Wilkins et al. (1995). The effect of waste minimization was obtained from the site-totaled inventories and annual generation rates and the assumption that inventory and 20 years of generation will be treated and disposed of in a 10-year period. With the assumed 50% source reduction, in effect 20 years of generation is reduced to 10 years of generation. The ratio of inventory plus 10 years of generation to inventory plus 20 years of

generation gives the impact of waste minimization. This ratio is applied to the contribution to the waste load at a treatment site from a generation site. From these tables it is seen that waste minimization is more effective in reducing the CH non-alpha waste load than the CH alpha waste loads. For CH non-alpha LLMW, the assumed 50% source reduction is estimated to reduce the overall waste load by approximately 36%, while the same percentage decrease in annual generation of CH alpha LLMW is estimated to decrease CH alpha waste load by only approximately 9%. Table G-11 gives the estimated percentage decreases from a 50% source reduction for RH non-alpha LLMW.

Table G–9. Percentage Reduction in Annual Treatment Throughput of Waste Management CH Non-Alpha LLMW

Site	Case 2a[a]		Case 7[a]		Case 17[a]	
	Current[b]	% Reduct[c]	Current	% Reduct	Current	% Reduct
ANL-E	8.4E+02	49	---[c]	---	---	---
ANL-W	2.0	21	---	---	---	---
Ames	5.6E-02	12	---	---	---	---
BCL	1.8E+02	50	---	---	---	---
BNL	1.9E+01	28	---	---	---	---
Bettis	2.9	23	---	---	---	---
Colonie	1.1	0	---	---	---	---
Charleston	1.5	46	---	---	---	---
ETEC	1.2E+02	24	---	---	---	---
FEMP	2.6E+02	1	---	---	---	---
GA	4.3	1	---	---	---	---
GJPO	1.8E-01	29	---	---	---	---
Hanford	3.5E+03	45	3.5E+03	46	1.5E+04	36
INEL	1.8E+02	30	1.8E+02	27	---	---
ITRI	3.5	46	---	---	---	---
KAPL-S	8.3	49	---	---	---	---
KAPL-K	1.0E+01	49	---	---	---	---
KAPL-W	4.0	50	---	---	---	---
KCP	8.1E-02	0	---	---	---	---
LANL	6.5E+01	25	6.5E+01	32	---	---
LBL	2.8E+01	46	---	---	---	---
LEHR	8.5E-01	17	---	---	---	---

Table G–9. Percentage Reduction in Annual Treatment Throughput of Waste Management CH Non-Alpha LLMW

Site	Case 2a[a]		Case 7[a]		Case 17[a]	
	Current[b]	% Reduct[c]	Current	% Reduct	Current	% Reduct
LLNL	1.9E+02	47	---	---	---	---
Mound	2.2E-03	25	---	---	---	---
Mare Is	5.2	41	---	---	---	---
Norfolk	6.0E-01	50	---	---	---	---
NTS	5.8E-02	12	---	---	---	---
K-25	9.6E+02	30	---	---	---	---
Y-12	4.4E+01	19	---	---	---	---
ORR	3.0E+01	36	6.3E+03	25	---	---
PGDP	5.8E+01	0	---	---	---	---
Pearl H	5.6E-01	32	---	---	---	---
Ports Nav	1.2E-01	33	---	---	---	---
PORTS	2.8E+03	42	2.8E+03	41	---	---
PPPL	1.6E-03	25	---	---	---	---
Puget So	1.7E+01	33	---	---	---	---
Pantex	6.9E+01	40	---	---	---	---
RFETS[d]	0	NA	1.9E-01	20	---	---
RMI	2.9	12	---	---	---	---
SNL-NM	6.6	0	---	---	---	---
SNL-CA	1.1E+01	45	---	---	---	---
SRS	9.8E+02	38	9.8E+02	38	---	---

[a] Case 2a is the Decentralized Alternative; Case 7 is Regionalized Alternative 2 with CH non-alpha treatment at 7 sites and disposal at 6 sites; Case 17 is the Centralized Alternative with all CH non-alpha treatment and disposal at Hanford.
[b] Annual throughput in m^3.
[c] Percentage reduction annual throughout from a 50% reduction in annual generation.
[d] Not a regional treatment site.

The percentage reductions in the waste loads from a 50% source reduction for disposal of waste management CH non-alpha LLMW and waste management CH alpha LLMW are given in Tables G-12 and G-13, respectively. As can be shown from these tables, the impact of the assumed source reduction on disposal waste loads is similar to the impact on treatment waste loads, namely, approximately a 35% reduction for non-alpha waste and a 9% reduction for alpha waste.

Some existing facilities in the DOE complex were assumed to be used for treatment of LLMW. Conversely, because disposal facilities for LLMW would have to be permitted pursuant to RCRA and existing DOE disposal facilities do not have such permits, it was assumed that there are no existing disposal facilities for LLMW. Table G-14 gives the capacities of existing treatment facilities, except for aqueous treatment, the capacities required without source reduction, and the capacities required with the assumed source reduction. From the table it is seen that the existing capacities are adequate; therefore, waste minimization would not reduce the need for new facilities for treatment of WM LLMW.

Table G–10. Reduction in Annual Treatment Throughput of Waste Management CH Alpha LLMW

Site	Case 2a[a]		Case 7[a]		Case 17[a]	
	100%	% Reduct	100%	% Reduct	100%	% Reduct
Hanford	---[b]	---	---	---	1.0E+0	9
INEL	2.5E+03	0	2.5E+03	4	---	---
LANL	2.1E+02	42	2.1E+02	42	---	---
LLNL	2.0E+02	48	---	---	---	---
RFETS	6.9E+03	10	6.9E+03	10	---	---
SRS	4.1E+02	14	4.2E+02	14	---	---

[a] Case 2a is the Decentralized Alternative; Case 7 is Regionalized Alternative 2 with CH non-alpha treatment at 7 sites and disposal at 6 sites; Case 17 is the Centralized Alternative with all CH non-alpha treatment and disposal at Hanford.
[b] Not a regional treatment site.

Table G–11. Percentage Reduction in Annual Treatment and Disposal Throughput of Waste Management RH Non-Alpha LLMW

Site	Treatment (m^3/yr)	Disposal (m^3/yr)	Reduction (%)
Hanford	7.4E-02	1.2E-02	0
INEL	8.6E+02	1.5E+02	49
ORR	3.5E+02	7.0E+02	17
SRS	2.8	8.8E-01	47

G.2.3.2 Cost Savings

Cost savings associated with the treatment, disposal, and transportation of CH waste management LLMW are considered. These are based on planning-level life-cycle costs for 10 years of operations (see Sherick and Shropshire, 1995). As with LLW, treatment and disposal costs are divided into operations costs and construction (or capital) costs. Operations costs are assumed to be proportional to throughput and (waste load). Capital costs are assumed to be proportional to throughput also, except when there is existing capacity for a specific treatment step that is inadequate for the waste load. However, as shown in Table G-14, the existing capacity is adequate for the waste load. Therefore, capital costs are also assumed to be proportional to waste load, because no new capacity is needed when there is existing capacity.

Table G–12. Percentage Reduction in Annual Disposal Throughput for Waste Management CH Non-Alpha LLMW

Disposal Site	Case 2a[a]		Case 7[a]		Case 17[a]	
	100%[b]	% Reduct[c]	100%	% Reduct	100%	% Reduct
ANL-E	5.8E+02	49	---	---	---	---
BNL	8.4E+01	28	---	---	---	---
FEMP	1.1E+02	1	---	---	---	---
Hanford	1.3E+03	46	1.3E+03	46	5.3E+03	35
INEL	4.3E+01	30	1.4E+02	26	---	---
LANL	1.1E+01	25	3.3E+02	33	---	---
LLNL	1.9E+02	34	---	---	---	---
ORR	1.5E+03	25	1.1E+04	32	---	---
Pantex	2.0E+01	40	---	---	---	---
PGDP	2.2E+01	0	---	---	---	---
PORTS	5.8E+02	42	---	---	---	---
RFETS	5.7E-01	29	---	---	---	---
SNL-NM	1.4	1	---	---	---	---
SRS	4.4E+02	38	4.5E+02	38	---	---
WVDP	1.0E+01	46	---	---	---	---

[a] Case 2a is the Decentralized Alternative with 16 disposal sites; Case 7 is Regionalized Alternative 2 with CH non-alpha treatment at 7 sites and disposal at 6 sites; Case 17 is the Centralized Alternative with all CH non-alpha treatment and disposal at Hanford.
[b] Annual throughput in m^3.
[c] Percentage reduction annual throughput from a 50% reduction in annual generation.

Table G–13. Percentage Reduction in Annual Disposal Throughput for Waste Management CH Alpha LLMW

Disposal Site	Case 2a[a]		Case 7[a]		Case 17[a]	
	100%[b]	% Reduct[c]	100%	% Reduct	100%	% Reduct
Hanford	---	---	---	---	3.2E+03	9
INEL	6.1E+02	0	7.0E+02	6	---	---
LANL	5.6E+01	21	2.4E+03	10	---	---
LLNL	8.1E+01	48	---	---	---	---
RFETS	2.3E+03	10	---	---	---	---
SRS	1.1E+02	14	1.1E+02	14	---	---

[a] Case 2a is the Decentralized Alternative with 16 disposal sites; Case 7 is Regionalized Alternative 2 with CH non-alpha treatment at 7 sites and disposal at 6 sites; Case 17 is the Centralized Alternative with all CH non-alpha treatment and disposal at Hanford.
[b] Annual throughput in m^3.
[c] Percentage reduction annual throughout from a 50% reduction in annual generation.

Estimates of the impact of a 50% source reduction for the three alternatives being considered are given in Table G-15 for CH waste management LLMW, both non-alpha and alpha. The transportation, operations, and capital costs without waste minimization are from Sherick and Shropshire (1995). The table indicates that for the assumed source reduction and lineality between waste load and cost, substantial savings may result from waste minimization. These savings range from over $3 billion for the Decentralized Alternative to nearly $2 billion for the Centralized Alternative.

G.2.3.3 Human Health Risk Reduction

Reductions in human health risk for a 50% source reduction are estimated for routine operations of treatment facilities and from long-term releases from disposal facilities. As before, cancer incidence is taken as the measure of human health risk. For treatment facilities, cancer incidence among two populations are considered, the offsite population and occupational workers. For disposal facilities, the risk to all nearby farm family generations is considered. For LLMW, cancer incidence arises from exposure to chemical carcinogens as well as from radiological doses. The estimated reductions in cancer incidence among the offsite population near treatment site, among occupational workers at treatment sites, and among farm family generations near disposal sites are given in Tables G-16 through G-18, respectively. As before, it is assumed that health risk decreases linearly with waste load.

Table G–14. Effect of WMin/PP Source Reduction on the Need for New Facilities to Meet Waste Management CH Non-Alpha LLMW Treatment Needs

Site/Facility	Existing Capacity (kg/h)	Current WMin/PP	Capacity Required (kg/h)		
			Case 2a[a]	Case 7[a]	Case 17[a]
ANL-E					
DEACT	5.4	Current	---[b]	---	---
		WMin/PP			
ETEC					
RMERC	5.0E-02	Current	---	---	---
		WMin/PP	---	---	---
Hanford					
DEACT	9.5E+01	Current	---	---	---
		WMin/PP	---	---	---
GROUT	2.1E+03	Current	3.1E+02	3.3E+02	1.1E+03
		WMin/PP	1.6E+02	1.8E+02	6.8E+02
INEL					
INCIN	3.2E+02	Current	7.3	1.5E+01	---
		WMin/PP	5.0	1.1E+01	---
GROUT	3.8E+02	Current	8.6	4.1E+01	1.0E-02
		WMin/PP	5.9	3.0E+01	7.E-03
LANL					
PBRCR	1.4E+01	Current	---	---	---
		WMin/PP	---	---	---
LBL					
GROUT	2.1E+02	Current	2.3E-01	---	---
		WMin/PP	1.3E-01	---	---
ORR					
INCIN	1.9E+03	Current	5.9E+02	6.4E+02	---
		WMin/PP	3.8E+02	5.0E+02	---
GROUT	6.8E+02	Current	4.1E+02	4.2E+02	8.2E-01
		WMin/PP	2.6E+02	3.1E+02	6.4E-01
Pantex					
GROUT	2.5E+01	Current	3.8	7.3E-02	7.3E-02
		WMin/PP	2.3	4.4E-02	4.4E-02
RFETS					
GROUT	3.8E+03	Current	---	1.5E-02	---
		WMin/PP	---	1.2E-02	---
SRS					
INCIN	1.1E+03	Current	1.7E+02	1.7E+02	---
		WMin/PP	1.0E+02	1.1E+02	---
GROUT	5.9E+03	Current	5.0E+1	5.0E+01	1.0E-02
		WMin/PP	3.1E+01	3.1E+01	6.8E-03

[a] Case 2a is the Decentralized Alternative with 16 disposal sites; Case 7 is Regionalized Alternative 2 with CH non-alpha treatment at 7 sites and disposal at 6 sites; Case 17 is the Centralized Alternative with all CH non-alpha treatment and disposal at Hanford. INCIN = incineration; DEACT = deactivation; RMERC = mercury removal; PBRCR = lead recovery; GROUT = grout stabilization.

[b] No throughput for this process for this alternative.

Table G–15. Effect of Waste Minimization on Cost of Treatment, Disposal, and Transportation of CH Waste Management LLMW (in dollars)

Case/Operation	Non-Alpha		Alpha[b]	
	Current	WMin/PP	Current	WMin/PP
Case 2A[a]				
Treatment				
Operations & Maintenance	4.0E+09	2.6E+09	2.2E+09	1.8E+09
Capital	2.0E+09	1.4E+09	1.5E+09	1.3E+09
Disposal				
Operations & Maintenance	1.1E+09	6.6E+08	7.6E+08	7.0E+08
Capital	2.7E+08	1.7E+08	3.0E+08	3.0E+08
Transportation	4.8E+05	3.5E+05	1.7E+05	1.4E+05
TOTAL	7.4E+09	4.8E+09	4.8E+09	4.1E+09
Case 7[a]				
Treatment				
Operations & Maintenance	2.4E+09	1.6E+09	2.2E+09	1.9E+09
Capital	9.1E+08	6.0E+08	1.6E+09	1.4E+09
Disposal				
Operations & Maintenance	8.1E+08	4.9E+08	6.4E+08	5.8E+08
Capital	1.8E+08	1.0E+08	9.1E+07	8.2E+07
Transportation	3.8E+06	2.4E+06	2.1E+06	1.8E+06
TOTAL	4.3E+09	2.8E+09	4.5E+09	4.0E+09
Case 17[a]				
Treatment				
Operations & Maintenance	2.3E+09	1.6E+09	1.6E+09	1.5E+09
Capital	7.6E+08	5.2E+08	1.2E+09	1.0E+09
Disposal				
Operations & Maintenance	6.3E+08	3.4E+08	4.1E+08	3.8E+08
Capital	5.4E+07	2.9E+07	4.3E+07	3.9E+07
Transportation	9.7E+06	6.7E+06	3.9E+06	3.4E+06
TOTAL	3.8E+09	2.5E+09	3.3E+09	2.9E+09

[a] Case 2a is the Decentralized Alternative with 16 disposal sites; Case 7 is Regionalized Alternative 2 with CH non-alpha treatment at 7 sites and disposal at 6 sites; Case 17 is the Centralized Alternative with all CH non-alpha treatment and disposal at Hanford.
[b] CH non-alpha waste generated at INEL and LANL are treated at INEL and LANL CH alpha facilities.

From Table G-16, it is seen that the effectiveness of waste minimization in reducing health risk to the offsite population near treatment sites varies significantly with alternative. For the Decentralized Alternative, this risk is dominated by the risk at LLNL and the health risk reduction is 47%. In contrast, the health risk for treatment at Hanford dominates for the Centralized Alternative 17 (Case 17) and is reduced by only 36%. From Table G–17, the aggregate reduction in occupational worker health risk at treatment sites is not as strongly dependent on alternative and is approximately 35% for all three alternatives. From Table G–18, the aggregate reduction in health risk from the assumed source reduction

from waste minimization varies from 42% for Regionalized Alternative 2 (Case 7) to 35% for the Centralized Alternative (Case 17).

Table G–16. Percentage Reduction in Risk to the Offsite Population[a] for Treatment of CH Waste Management LLMW

Site	Case 2a[b]		Case 7[b]		Case 17[b]	
	100%[b]	% Reduct[c]	100%	% Reduct	100%	% Reduct
ANL-E	4.5E-03	49	2.1E-05	49	2.1E-05	49
BNL	4.1E-05	28	1.9E-07	28	1.9E-07	28
ETEC	6.5E-04	24	3.1E-06	24	3.1E-06	24
FEMP	9.1E-05	1	6.3E-07	1	6.3E-07	1
Hanford	5.0E-03	45	4.5E-02	45	8.5E-02	36
INEL	1.8E-04	30	2.1E-03	26	1.7E-05	30
KAPL-K	1.0E-03	49	8.9E-07	49	8.9E-07	49
KCP	1.3E-05	0	8.4E-09	0	8.4E-09	0
LANL	2.0E-03	25	2.9E-03	32	1.3E-04	25
LBL	3.5E-02	46	5.3E-08	46	5.3E-08	46
LLNL	5.2E-01	47	2.2E-06	47	2.2E-06	47
Mound	4.3E-04	25	1.1E-07	25	1.2E-07	25
NTS	1.8E-09	12	3.3E-14	12	3.3E-14	12
ORR	3.7E-03	25	4.1E-03	25	2.5E-05	25
Pantex	1.2E-05	40	8.0E-06	40	8.0E-06	40
PGDP	4.1E-04	0	2.8E-06	0	2.8E-06	0
PORTS	1.2E-05	42	3.6E-04	42	1.3E-07	42
RFETS	3.5E-04	20	3.3E-04	20	2.4E-05	20
SNL-NM	4.7E-04	0	6.1E-08	0	6.1E-08	0
SRS	5.9E-03	38	6.0E-03	38	4.7E-06	38
WVDP	8.7E-07	50	5.9E-07	50	6.0E-07	50
Total	5.8E-01	47	6.1E-02	42	8.5E-02	36

[a] Case 2a is the Decentralized Alternative; Case 7 is Regionalized Alternative 2 with CH non-alpha treatment at 7 sites and disposal at 6 sites; Case 17 is the Centralized Alternative with all CH non-alpha treatment and disposal at Hanford.
[b] Cancer incidence among the offsite population from radiation and chemical carcinogens.
[c] Percentage reduction in risk based on a 50% reduction in annual generation of CH non-alpha LLMW.

Table G–17. Percentage Reduction in Risk to Workers[a] for Treatment of CH Waste Management LLMW

Site	Case 2a[b]		Case 7[b]		Case 17[b]	
	100%	% Reduct[c]	100%	% Reduct	100%	% Reduct
ANL-E	6.7E-02	49	3.6E-02	49	3.6E-01	49
BNL	4.3E-04	28	2.0E-04	28	2.0E-04	28
ETEC	3.8E-03	24	2.2E-03	24	2.2E-03	24
FEMP	1.1E-03	1	8.8E-04	1	8.8E-04	1
Hanford	3.6E-01	45	5.0E-01	45	1.8E+00	36
INEL	3.6E-01	30	3.9E-01	26	1.8E-01	30
KAPL-K	6.2E-03	49	2.2E-02	49	2.2E-03	49
KCP	1.2E-04	0	2.8E-06	0	2.8E-06	0
LANL	5.5E-03	25	8.2E-03	32	2.4E-03	25
LBL	1.3E-04	46	7.4E-05	46	7.4E-05	46
LLNL	2.8E-02	47	2.2E-03	47	2.2E-03	47
Mound	4.7E-05	25	4.3E-05	25	4.6E-05	25
NTS	9.1E-07	12	9.1E-07	12	9.1E-07	12
ORR	6.2E-01	25	4.2E-01	25	8.4E-02	25
Pantex	1.1E-01	40	5.8E-04	40	5.8E-04	40
PGDP	8.5E-04	0	5.2E-04	0	5.2E-04	0
PORTS	5.6E-03	42	2.7E-01	42	2.9E-03	42
RFETS	4.1E-03	20	4.6E-03	20	3.5E-03	20
SNL-NM	1.2E-03	0	6.1E-05	0	6.1E-05	0
SRS	3.7E-01	38	3.8E-01	38	1.1E-01	38
WVDP	1.0E-04	50	9.7E-05	50	1.0E-04	50
Total	1.9E+00	34	2.0E+00	36	2.5E+00	37

[a] Cancer incidence among the workers onsite from radiation and chemical carcinogens.
[b] Case 2a is the Decentralized Alternative; Case 7 is Regionalized Alternative 2 with CH non-alpha treatment at 7 sites and disposal at 6 sites; Case 17 is the Centralized Alternative with all CH non-alpha treatment and disposal at Hanford.
[c] Percentage reduction in risk based on a 50% reduction in annual generation of CH non-alpha LLMW.

G.2.4 HAZARDOUS WASTE

Hazardous waste contains materials that are hazardous under RCRA and other Federal environmental statutes (such as the Toxic Substances Control Act), but does not contain radioactive materials. As with

LLMW, HW is treated primarily to meet statutory requirements. Estimates of the effect of source reduction on HW facilities are based on information in the hazardous waste technical report (Lazaro et al., 1995); Appendix D, Waste Management Facility Human Health Risk; and the waste management costs technical report (Sherick and Shropshire, 1995).

Table G–18. Percentage Reduction in Risk[a] from Disposal of CH Waste Management LLMW

Disposal Site	Case 2a[b]		Case 7[b]		Case 17[b]	
	100%	% Reduct[c]	100%	% Reduct	100%	% Reduct
ANL-E	1.0E-01	49	---	---	---	---
BNL	3.4E-03	28	---	---	---	---
FEMP	1.2E-03	1	---	---	---	---
Hanford	5.6E-01	46	5.5E-01	46	2.0E+00	35
INEL	5.9E-05	30	1.3E-04	26	---	
LANL	0	25	0	33	---	---
LLNL	1.6E-06	34	---	---	---	---
ORR	1.9E-04	25	5.0E-04	32	---	---
Pantex	1.2E-05	40	---	---	---	---
PGDP	2.0E-07	0	---	---	---	---
PORTS	3.4E-03	42	---	---	---	---
RFETS	1.6E-01	29	---	---	---	---
SNL-NM	3.0E-03	1	---	---	---	---
SRS	4.5E-01	38	4.5E-01	38	---	---
WVDP	5.1E-03	46	---	---	---	---
Total	1.29E+00	41	1.0E+00	42	2.0E+00	35

[a] Cancer incidence among all farm family generations from radiation and chemical carcinogens.
[b] Case 2a is the Decentralized Alternative with 16 disposal sites; Case 7 is Regionalized Alternative 2 with CH non-alpha treatment at 7 sites and disposal at 6 sites; Case 17 is the Centralized Alternative with all CH non-alpha treatment and disposal at Hanford.
[c] Percentage reduction in risk based on a 50% reduction in annual generation of CH non-alpha LLMW.

The vast majority of HW is contaminated wastewater and is always treated onsite in wastewater treatment facilities. This appendix addresses HW other than contaminated wastewater, that is, HW that is transferred for treatment at specialized facilities, either onsite or offsite. Most, approximately three–quarters, of the HW generated in the DOE complex is generated at 11 installations. This appendix considers only HW generated at these 11 installations.

G.2.4.1 Waste Load Reductions

Table G–19 contains quantities of HW transferred for treatment by type of treatment for 1992 for the 11 top HW-generating installations. Storage of HW is limited by RCRA to 90 days at unpermitted facilities. Therefore, unlike the other waste types, there is no year-to-year storage of HW and no inventories to be worked off with the HW generated annually. Also, because there is no long-term storage, waste loads for HW generated by waste management operations are based on 20 years of generation being treated and disposed of in 20 years. Thus, a given percentage reduction in annual production is estimated to result in the same percentage reduction in treatment waste loads. For a 50% across-the board reduction in annual generation, the values in Table G–19 would be cut in half.

Table G–19. Technologies Used to Treat Hazardous Waste Transfers (1992)

Treatment Technology	Quantity[a] (kg)	Comments
Incineration	1.6E+06	This is the principal form of treatment for a wide range of organic wastes.
Organic Removal/Recovery	9.4E+05	This treatment technology is primarily fuel burning or blending, and solvent recycling or distillation.
Stabilization	3.8E+05	This treatment technology is most commonly used for inorganic waste. The waste is mixed with solidification agents, such as Portland cement, to meet disposal facility waste acceptance criteria.
Deactivation	1.7E+05	Treatment technologies that are so classified include neutralization of corrosive waste; and controlled detonation, reaction, or deactivation of explosives.
Metal Removal/Recovery	1.2E+05	This technology involves precipitation of heavy metals from aqueous solutions. The resulting precipitate may be further treated to recover metals or be stabilized prior to land disposal.
Mercury Recovery/Treatment	1.1E+05	This is a specialized treatment (e.g., mercury roasting or retorting, amalgamation, or incineration of organic wastes containing mercury) that is offered only by a few commercial facilities in the country.
Aqueous Treatment	4.9E+04	This type of treatment includes a range of technologies including biological treatment, wet air oxidation, and chemical oxidation/reduction.
Recycling	1.3E+03	Most DOE "recycled" wastes are lead acid storage batteries and scrap metals.

[a] Quantities are based on offsite transfers from the eleven top HW generators.

G.2.4.2 Cost Savings

Two of the alternatives considered in the WM PEIS are elaborated here. The first is Regionalized Alternative 2 in which there are two DOE treatment hubs: one in the east at ORR and the second in the west at INEL. In this alternative, all HW is shipped to the DOE hubs where approximately 90% of treatment is performed. Three treatments (stabilization, battery recycling, and mercury removal) take place at commercial facilities after shipment from DOE hubs. The second case is Regional Alternative 1 in which HW is shipped to five DOE hubs. The DOE hubs perform roughly half of the organic removal and recovery treatment and ship treated HW to commercial facilities for other treatment.

Table G-20 shows the cost savings for a 50% across-the-board reduction in annual generation based on cost information in the waste management costs technical report (Sherick and Shropshire, 1995). The table breaks out costs according to treatment, disposal, and transportation; or the cost of treatment at commercial facilities. In Lazaro et al. (1995), existing facilities for treatment of HW are identified. However, the cost estimates in Sherick and Shropshire (1995) are based on the assumption that these existing facilities are dedicated to treatment of LLMW and that all HW treatment facilities at DOE installations are new facilities. Therefore, the values in Table G-20 are based on the assumption that both operations and construction cost savings are proportional to source reduction.

G.2.4.3 Human Health Risk Reductions

Reduction in human health risk for a 50% across-the-board reduction in annual generation of HW from routine operations of hazardous waste facilities were estimated for the same two alternatives (regionalized 2 and regionalized 1) considered above. The human health risk considered cancer incidence for three types of receptors: the onsite population of noninvolved workers, the offsite population, and workers at TSD facilities. Risks to the onsite and offsite population are proportional to throughput. Aggregate risks to TSD workers are proportional to the number of such workers, which will be assumed to be proportional to throughput. The estimated reduction for 20 years of operations is tabulated by DOE site and case in Table G-21. With these assumptions, the reductions in human health risks are 50% of the human health risks given in Appendix D.

G.2.5 Transuranic Waste

TRUW is defined as radioactive waste contaminated with alpha-particle-emitting transuranic radionuclides with half-lives greater than 20 years and concentrations greater than 100 nCi/g gram at the time of assay. The DOE distinguishes between CH TRUW (packaged waste with an external surface dose rate not exceeding 200 mrem/hr) and RH TRUW (packaged waste with an external surface dose rate exceeding 200 mrem/hr). TRUW generated prior to 1970 is buried in shallow landfill-type disposal grounds and is considered as an ER waste. TRUW waste generated since 1970 is considered a waste management waste. Some TRUW wastes are contaminated with hazardous materials. Such material can be treated using the same processes as for LLMW, with additional precautions appropriate for the radioactive component being TRUW rather than LLW.

Table G–20. Cost Savings at HW Treatment Hubs and from WMin/PP Source Reduction ($1,000)

Site	Regionalized 2[a]	Regionalized 1[b]
ANL-E		
Transportation	2.25E+01	1.95E+01
Commercial	---	---
Fermi		
Transportation	8.5	9
Commercial	---	---
Hanford		
Treatment	---	3.00E+04
Disposal	---	6.98E+02
Transportation	1	1.40E+01
Commercial	---	4.16E+03
INEL		
Treatment	6.39E+04	1.13E+04
Disposal	1.69E+03	3.24E+02
Transportation	2.65E+01	4
Commercial	2.73E+03	9.98E+02
KCP		
Transportation	5.80E+01	4.7E+01
Commercial	---	---
LANL		
Treatment	---	2.81E+04
Disposal	---	6.98E+02
Transportation	1.95E+01	7
Commercial	---	4.02+03

Table G–20. Cost Savings at HW Treatment Hubs and from WMin/PP Source Reduction ($1,000)—Continued

Site	Regionalized 2[a]	Regionalized 1[b]
LLNL		
Transportation	1.04E+02	9.60E+01
Commercial	---	---
ORR		
Treatment	5.49E+04	3.30E+04
Disposal	1.32E+03	7.92E+02
Transportation	1	8.50
Commercial	1.11E+04	1.46E+04
Pantex		
Transportation	2.75E+01	1.10E+01
Commercial	---	---
SNLA		
Transportation	6.5E+01	2.90E+01
Commercial	---	---
SRS		
Treatment	---	1.39E+04
Disposal	---	3.74E+02
Transportation	1.95E+01	1.30E+01
Commercial	---	1.49E+03
Total		
Treatment	1.19E+05	1.16E+05
Disposal	3.01E+03	2.89E+03
Transportation	3.53E+02	2.57E+02
Commercial	1.38E+04	2.53E+04
Total	1.36E+05	1.44E+05

[a] This case has two DOE treatment hubs, one in the east and one in the west; only hubs ship to commercial facilities.
[b] This case has five DOE treatment hubs; only hubs ship to commercial facilities.

Estimates of the effect of source reduction on TRUW facilities are based on information in the transuranic waste technical report (Hong et al., 1995); Appendix D, Waste Management Facility Human Health Risk Estimates; and the waste management costs technical report (Sherick and Shropshire, 1995).

Table G–21. Reduction in Cancer Incidence[a] at DOE HW Treatment Hubs from WMin/PP Source Reduction

Hub/Receptor	Regionalized 1	Regionalized 2
Hanford		
Noninvolved worker population	---	1.3E-03
Offsite population	---	2.1E-03
TSD workers	---	1.4E-01
INEL		
Noninvolved worker population	6.5E-04	7.0E-05
Offsite population	4.8E-04	5.0E-05
TSD workers	3.7E-01	3.8E-02
LANL		
Noninvolved worker population	---	4.7E-03
Offsite population	---	1.0E-02
TSD workers	---	1.5E-01
ORR		
Noninvolved worker population	1.6E-02	5.5E-03
Offsite population	4.7E-02	1.8E-02
TSD workers	5.5E-01	2.1E-01
SRS		
Noninvolved worker population	---	3.0E-04
Offsite population	---	6.0E-04
TSD workers	---	4.6E-02
Total		
Noninvolved worker population	1.7E-02	1.2E-02
Offsite population	4.8E-02	3.1E-02
TSD workers	9.2E-01	5.8E-01

[a] Cancer incidence arising from 20 years of treatment.

G.2.5.1 Waste Load Reduction

Tables G–22 and G–23 contain estimates of the effect on generating site waste loads of an across-the-board 50% source reduction of CH TRUW and RH TRUW, respectfully. Inventory and generation rates for an installation are obtained from volume-weighted averages over treatment classes. The waste loads are based on inventory and 20 years of generation being treated in 10 years. The inventories and waste loads include the following waste stream categories from the DOE 1994 *Mixed Waste Inventory Report*: 1000 (aqueous liquids); 2000 (organic liquids); 3000 (solid process wastes); 4000 (soils); and 5000 (debris). Waste categories 6000 (special: lab packs with and without reactive metals) and 7000 (inherently hazardous; for example, reactive metals, mercury, and cadmium batteries) are not included because impacts of their

treatment, storage, and transportation were not considered elsewhere in the WM PEIS. The percentage differences in waste load attributed to source reduction are smaller than for the other waste types considered because the inventories are larger relative to annual generation. Thus, changes in annual generation rates have relatively smaller effects on waste loads. Averaged over the DOE complex, a 50% reduction in annual generation of CH TRUW is estimated to reduce CH TRUW waste loads by 15%, and a 50% reduction in annual generation of RH TRUW is estimated to reduce RH TRUW waste loads by 27%.

Table G–22. Effect of WMin/PP Source Reduction on CH-TRUW Generating Site Waste Loads

TRUW Site	Inventory (m^3)	Generation Rate (m^3/yr)	Waste Loads[a] (m^3/yr)		Percentage Difference
			Current	WMin/PP	
ANL-E	1.5E+01	4.7E+01	9.5E+01	4.8E+01	49%
Hanford	8.2E+03	2.8E+02	6.8E+02	4.0E+02	41%
INEL	3.8E+04	1.4E+01	3.8E+03	3.8E+03	1%
LANL	8.1E+03	1.3E+02	1.1E+03	9.3E+02	12%
LBL	8.0E-01	1.0E-02	1.0E-01	9.0E-03	10%
LLNL	4.0E+02	7.4E+01	1.7E+02	1.1E+02	33%
Mound	1.6E+02	0	1.6E+01	1.6E-01	0%
Nevada	6.1E+02	0	6.1E+01	6.1E+01	0%
PGDP	1.4E+01	0	1.4	1.4	0%
RFP	1.3E+03	2.4E+02	6.0E+02	3.7E+02	39%
SNLA	1.0	0	1.0E-01	1.0E-01	0%
SRS	5.4E+03	6.1E+02	1.7E+03	1.1E+03	35%
UMC	1.0E-01	2.0	4.0	2.0	50%
Total	6.2E+04	1.4E+03	8.9E+03	7.6E+03	15%

[a] Assumes inventory and 20 years of generation are treated in 10 years; for the WMin/PP case, the annual generation rate is half the current generation rate. Includes waste stream categories: aqueous liquids (1000); organic liquids (2000); solid process residues (3000); soils (4000); and debris (5000).

Table G–23. Effect of WMin/PP Source Reduction on RH TRUW Generating Site Waste Loads

TRUW Site	Inventory (m^3)	Generation Rate (m^3/yr)	Waste Loads[a] (m^3/yr)		Percentage Differences
			Current	WMin/PP	
ANL-E	0.00	1.7E+01	3.4E+01	1.7E+01	50%
Hanford	2.8E+03	1.8E+02	6.3E+02	4.5E+02	28%
INEL	1.1E+02	2.3E+01	5.7E+01	3.4E+01	40%
LANL	7.9E+01	5.0E-01	8.9	8.4	6%
ORR	1.1E+03	1.4E+01	1.4E+02	1.3E+02	11%
Total	4.1E+03	2.3E+02	8.7E+02	6.4E+02	27%

[a] Assumes inventory and 20 years of generation are treated in 10 years; for the WMin/PP case, the annual generation rate is half the current generation rate. Includes waste stream categories: aqueous liquids (1000); organic liquids (2000); solid process residues (3000); soils (4000); and debris (5000).

The effect of a 50% across-the-board source reduction is considered for four representative CH TRUW alternatives and one RH TRUW alternative. The four CH TRUW cases are: Regionalized Alternative 3, 3 regional sites with treatment to RCRA compliance (Case 8); Regionalized Alternative 2, 5 regional sites with treatment to RCRA compliance (Case 6); Regionalized Alternative 1, 5 regional sites with stabilization treatment (Case 5); and the Decentralized Alternative, 16 sites treating to the Waste Isolation Plant Project (WIPP) waste acceptance criteria (WAC) (Case 4). These four cases provide diversity in the number of treatment sites and the level of treatment. The RH alternative has two sites with RCRA treatment (Case 15). The effect of this source reduction on the waste loads at the regional treatment facilities for the three regional site and five regional site CH TRUW cases and for the two regional site RH TRUW cases is given in Table G–24. For the Decentralized Alternative, with 16 sites treating to the WIPP WAC, the treatment takes place where the waste originates so that the percentage waste load reductions in Table G–22 apply.

Table G-24. Effect of WMin/PP Source Reduction on Regional Treatment Site TRUW Waste Loads

Regional Treatment Site	Percentage Decrease in Waste Load[a]		
	CH 3 Regional Sites	CH 5 Regional Sites	RH 2 Regional Sites
Hanford	41	41	29
INEL	7	1	NA
SRS	35	12	NA
LANL	NA[b]	35	NA
RFETS	NA	39	NA
ORR	NA	NA	18

[a] Assumes inventory and 20 years of generation are treated in 10 years; for the WMin/PP case, the annual generation rate is half the current generation rate.
[b] NA = not a regional treatment site.

G.2.5.2 Cost Savings

Cost savings from WMin/PP are considered for the four CH TRUW alternatives and for one RH TRUW alternative. Since disposal at WIPP is common to all alternatives, costs of disposal are considered to be beyond the scope of this appendix. The estimates of the effects of a 50% source reduction on costs used the effects of that source reduction on waste loads in Tables G-22 through G-24. Table G-24 was used for the effects on treatment at and transportation from regional treatment facilities. Tables G-22 (for CH waste) and Table G-23 (for RH waste) were used for the effects on treatment at and transportation from other installations.

Reductions in costs of treatment storage, and transportation were assumed to be proportional to reduction in waste load. In estimating the effect of source reduction on the facilities cost, the same distinction was made between situations where there are existing facilities and when there are no existing facilities, as in section G.2.2.2. Using information on existing facilities from Sherick and Shropshire (1995), Table G-25 summarizes the effect of a 50% source reduction on the need for new capacity. For the cases considered, the existing facilities at the Rocky Flats Environmental Technology Site (RFETS) are estimated to have adequate capacity regardless of source reduction. On the other hand, the facilities at INEL and SRS would not have sufficient capacity even with a 50% source reduction. At the Hanford Site, the existing waste characterization facility would have sufficient capacity for source reductions in excess of 14%.

Table G–25. Effect of WMin/PP Source Reduction[a] on the Need for New CH TRUW Facilities

Site/Facility[b]	Existing Capacity (kg/h)	Current/ WMin/PP	Total Capacity Required by Case (kg/h)			
			Case 4[c]	Case 5[c]	Case 6[c]	Case 8[c]
Hanford						
WCHAR	8.1E+01	Current	8.9E+01	8.9E+01	8.9E+01	8.9E+01
		WMin/PP	5.2E+01[d]	5.2E+01[d]	5.2E+01[d]	5.2E+01[d]
OSORT	8.1E+01	Current	---	1.4E+01[s]	1.4E+01[s]	1.4E+01[s]
		WMin/PP	---	8.4[s]	8.4[s]	8.4[s]
INEL						
RETRV	1.2E+02	Current	5.4E+02	5.4E+02	5.4E+02	5.4E+02
		WMin/PP	5.4E+02	5.4E+02	5.4E+02	5.1E+02
WCHAR	6.9E+01	Current	1.7E+02	1.7E+02	1.7E+02	1.7E+02
		WMin/PP	1.7E+02	1.7E+02	1.7E+02	1.7E+02
LANL						
AQWTR	2.0E+01	Current	---	---	9.5[s]	---
		WMin/PP	---	---	8.4[s]	---
INCIN	6.4E+01	Current	---	---	5.5E+01[s]	---
		WMin/PP	---	---	4.8E+01[s]	---
GROUT	4.5E-01	Current	2.3E+01	1.9E+01	2.1E+01	---
		WMin/PP	2.0E+01	1.7E+01	1.8E+01	---
RFETS						
AQWTR	1.5E+04	Current	---	---	6.0[s]	8.6E-01[s]
		WMin/PP	---	---	3.7[s]	5.4E-01[s]
CMPCT	7.7E+01	Current	---	5.2E+01[s]	5.5E+01[s]	---
		WMin/PP	---	3.2E+01[s]	3.4E+01[s]	---
GROUT	2.9E+01	Current	1.5E+01[s]	1.3E+01[s]	1.2E+01[s]	8.6E-01[s]
		WMin/PP	9[s]	7.6[s]	7.1[s]	8.6E-01[s]
SRS						
WCHAR	1.2E+01	Current	2.2E+01	2.2E+01	2.2E+01	2.2E+01
		WMin/PP	1.4E+01	1.4E+01	1.4E+01	1.4E+01
OSORT	1.2E+01	Current	---	1.1E+02	1.1E+02	1.1E+02
		WMin/PP	---	7.3E+01	7.3E+01	7.3E+01

[a] The required capacities for WMin/PP are based on an assumed 50% across-the-board source reduction.
[b] WCHAR = waste characterization; OSORT = open, dump, and sort; RETRV = retrieval; AQWTR = aqueous water treatment; INCIN = incineration; CMPCT = shredding and compaction; and GROUT = grout stabilization.
[c] Case 4: process and package CH TRUW to WIPP WAC at 16 sites (Decentralized Alternative); Case 5: treat CH TRUW at 5 sites to an intermediate level greater than that needed to meet current WIPP WAC (Regionalized 1); treat CH TRUW at 5 sites to RCRA land disposal requirements (LDR) (Regionalized 2); Case 8: treat at three sites to RCRA LDR (Regionalized 3).
[d] The existing capacity is estimated to be sufficient for a source reduction in excess of 14%.
[s] The existing capacity is sufficient regardless of source reduction.

The effects of the assumed source reduction on the planning level life-cycle costs of operations and maintenance, construction, and transportation are given in Tables G–26 and G–27 for the CH TRUW

alternatives and the RH TRUW alternative, respectively. For the CH TRUW alternatives, the assumed source reduction is estimated to result in a 22% reduction in costs, while the cost reduction for RH TRUW is estimated to be 26%.

G.2.5.3 Human Health Risk Reduction

Reductions in human health risk from a 50% across-the-board reduction in the annual generation of TRUW were estimated for the same four CH TRUW alternatives and RH TRUW alternative considered above. The human health risk considered was cancer incidence among the offsite population and among workers at TSD facilities. Risk reduction is assumed to be proportional to throughput reduction. With this assumption, the estimated reductions in risk for 10 years of operation of treatment facilities are given in Table G-28. The table shows that source reduction of CH TRUW is estimated to have a larger impact on human health risk to the public (approximately 30% reduction) than to TSD workers (approximately 18% reduction). This is because human health risks are estimated to be greater at SRS than at other installations. Because SRS has a relatively small ratio of inventory to annual generation, reductions in annual generation are relatively effective in reducing human health risk.

In contrast, health risks to TSD workers are more evenly spread among installations, with TSD workers at INEL having the greatest cancer incidence. At INEL, inventory of CH TRUW far exceeds annual generation. Thus, source reduction has a smaller impact on estimated cancer incidence among TSD workers.

Table G-26. Effect of WMin/PP on Costs for Four CH TRUW Alternatives[a] (in dollars)

Case[b]	O&M		Construction		Transportation	
	Current	WMin/PP	Current	WMin/PP	Current	WMin/PP
Case 4	4.0E+09	3.1E+09	1.4E+09	1.1E+09	2.0E+07	1.7E+07
Case 5	4.3E+09	3.3E+09	1.5E+09	1.2E+09	1.5E+07	1.3E+07
Case 6	4.8E+09	3.7E+09	2.0E+09	1.5E+09	1.2E+07	1.0E+07
Case 8	4.3E+09	3.3E+09	1.9E+09	1.4E+09	1.6E+07	1.3E+07

[a] Based on a 50% across-the-board source reduction
[b] Case 4: process and package CH TRUW to WIPP WAC at 10 larger sites (Decentralized Alternative); Case 5: treat CH TRUW at 5 sites to an intermediate level greater than that needed to meet current WIPP WAC (Regionalized 1); Case 6: treat CH TRUW at 5 sites to RCRA land disposal requirements (LDR) (Regionalized 2); Case 8: treat at 3 sites to RCRA LDR (Regionalized 3).

Table G–27. Effect of WMin/PP Source Reduction on Costs for an RH TRUW Alternative[a]

Site	O&M		Construction		Transportation	
	Current	WMin/PP	Current	WMin/PP	Current	WMin/PP
ANL-E	3.4E+06	1.7E+06	—	—	2.1E+05	1.0E+05
Hanford	7.7E+08	5.6E+08	4.2E+08	3.0E+08	1.3E+07	9.4E+06
INEL	3.9E+07	2.3E+07	1.0E+07	6.0E+06	3.5E+05	2.1E+05
LANL	1.2E+07	1.1E+07	3.3E+06	3.1E+06	1.0E+05	9.5E+04
ORR	3.6E+08	3.0E+08	2.6E+08	2.1E+08	5.5E+05	4.5E+05
Total	1.2E+09	9.0E+08	6.9E+08	5.2E+08	1.4E+07	1.0E+07

[a] This is for treatment to RCRA standards at two installations (Hanford and Oak Ridge); ANL-E ships to ORR; INEL and LANL ship to Hanford. It is assumed that there is a 50% across-the-board source reduction.

G.3 WMin/PP Practices Applied to Environmental Restoration and Decontamination and Decommissioning Activities

Environmental restoration activities are directed toward removal and treatment of legacy waste and pollutants. Waste and pollution may be generated during restoration activities just as they may be generated by decontamination and decommissioning (D&D) of plants and equipment and by dismantlement of weapons systems. Appendix B of the 1994 crosscut plan (DOE, 1994b) states that WMin/PP is applicable to the processes and techniques used to perform ER and D&D activities. In this section, application of WMin/PP practices to ER and D&D activities is discussed in view of the Office of Technology Development's Research, Development, Demonstration, Testing, and Evaluation (RDDT&E) program.

Table G–28. Effect of WMin/PP Source Reduction on Cancer Incidence for TRUW Alternatives

Case[a]	Offsite Population		TSD Workers	
	Current	WMin/PP[b]	Current	WMin/PP
Case 4	4.2E-04	3.1E-04	2.1	1.8
Case 5	5.9E-04	4.3E-03	2.2	1.8
Case 6	1.1E+01	7.9	2.2	1.8
Case 8	9.0	5.9	2.3	1.8
Case 15	1.8E-01	1.5E-01	3.3E-01	2.7E-01

[a] Case 4 (Decentralized Alternative): process and package CH TRUW to WIPP WAC at 16 sites; Case 5 (Regionalized Alternative): treat CH TRUW at 5 sites to an intermediate level greater than that needed to meet current WIPP WAC; Case 6 (Regionalized Alternative 2) treat CH TRUW at 5 sites to RCRA land disposal requirements (LDR); Case 8: treat at 3 sites to RCRA LDR; Case 15: treat RH TRUW at 2 sites to RCRA LDR.
[b] 50% across-the-board reduction in annual generation.

G.3.1 GROUNDWATER AND SOILS CLEANUP

Some of DOE's most pressing ER needs are for cleanup or containment of radioactive and hazardous contaminants in soils and groundwater. DOE is responsible for waste management and cleanup of more than 100 contaminated installations (containing approximately 3,700 contaminated sites) in 36 states (DOE, 1993a). These sites have over 26,000 acres with hazardous and radiologically contaminated surface water, groundwater, and soil that are in need of some measure of remediation. The following are a few examples of the extent of the contamination. At SRS and the Hanford Site, for example, soils and groundwater are contaminated with volatile organic compounds (VOCs). At the Nevada Test Site, more than 13 km^2 of soil are contaminated with plutonium, and a large quantity of soil is contaminated with uranium at the Fernald Environmental Management Project (FEMP) Site.

The DOE Office of Technology RDDT&E efforts include several programs directed for groundwater and soils cleanup. One concept being explored that is in conformity with WMin/PP principles is the Minimum Additive Waste Stabilization (MAWS) concept for stabilization of LLW and LLMW (DOE, 1994d). This new approach to vitrification uses multiple waste streams as substitutes for additives otherwise needed to be purchased. The MAWS concept integrates vitrification with other treatment technologies as appropriate, increasing waste loadings and reducing costs. The minimum additive waste stabilization technology is being demonstrated at FEMP. Applicable waste streams appear to be soils, sludges, groundwater, and ash and debris from burn pits.

Most of the RDDT&E programs in the ER area are integrated programs or demonstrations. In an integrated program, multiple technologies are assembled and evaluated as a cradle-to-grave solution to a representative generic environmental problem (DOE, 1993a). Some current RDDT&E integrated demonstrations are for VOCs in non-arid soils, VOCs in arid soils, cleanup of mixed waste landfills, uranium in soils, and in-situ remediation. Some of the technologies in the integrated demonstrations can be considered source reduction technologies. One such technology is methane-enhanced bioremediation, in which methane is injected via horizontal wells to become a food source for indigenous microorganisms known to be capable of degrading trichloroethylene (DOE, 1994e). By destroying contamination rather than transferring it from one medium to another, methane-enhanced bioremediation can be considered a source reduction technique (DOE, 1994e).

G.3.2 DECONTAMINATION, DECOMMISSIONING, AND RECYCLE

Because many facilities in the DOE complex are aging or changing their missions, there is a need to deactivate and decommission a large number of surplus buildings that currently contain radiological, hazardous, mixed, and special (such as asbestos) contaminants. Facilities in the DOE complex are assumed to contain substantial quantities of scrap steel, nickel, aluminum, and copper, which if decontaminated could be recycled and reused. The Office of Technology Development's RDDT&E program has a component concerned with reuse and recycle of both metal and concrete from decommissioned facilities (DOE, 1993a). Technologies being considered for the removal of both surface and volume contamination because they appear to have no technological barriers, worker safety problem, or public health limitations are:

- Surface decontamination of concrete using a microwave process
- Surface decontamination of metals using a laser process
- Volumetric decontamination of concrete using an electrostatic process
- Volumetric decontamination of stainless steel and of mild steel using a refining process
- Surface decontamination (internal) of equipment using a gas-phase process
- Volumetric decontamination of transite/asbestos using a melting process

This component includes developing industrial capacity to reuse and recycle the contaminated material.

Appendix G
References

DOE. *See* U.S. Department of Energy.

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Attachment to Appendix G

Table G.A–1. Effect of WMin/PP on LLW Treatment and Disposal at Regional Sites—Regionalized Alternative 2

Installation/Process	No WMin/PP ($)		WMin/PP ($)	
	Operations	Construction	Operations	Construction
FEMP				
Incinerate	1.93E+07	2.89E+07	1.11E+07	1.66E+07
Stabilize	6.97E+06	7.17E+07	3.94E+06	4.06E+07
Supercompact	1.01E+07	1.26E+06	5.07E+06	6.33E+05
Size Reduce	5.19E+07	2.08E+07	3.29E+07	1.32E+07
Package	---	---	---	---
Ship	3.27E+07	1.34E+07	1.96E+07	8.04E+06
Dispose	---	---	---	---
Hanford				
Incinerate	3.33E+06	2.01E+07	1.91E+06	1.15E+07
Stabilize	4.47E+06	3.53E+06	2.53E+06	1.20E+06
Supercompact	4.33E+07	6.49E+06	2.18E+07	24%[a]
Size Reduce	2.70E+08	7.44E+07	1.72E+08	4.72E+07
Package	5.41E+07	2.03E+07	3.33E+07	1.25E+07
Ship	2.61E+08	8.67E+07	1.61E+08	5.34E+07
Dispose	2.03E+09	1.52E+09	1.11E+08	8.33E+08
INEL				
Incinerate	2.90E+07	3.58E+07	1.67E+07	2.06E+07
Stabilize	1.13E+07	1.29E+07	6.38E+06	7.28E+06
Supercompact	1.00E+07	---	5.05E+06	---
Size Reduce	1.68E+08	---	1.06E+08	---
Package	7.91E+07	2.46E+07	4.88E+07	1.52E+07
Ship	9.04E+07	2.79E+07	5.58E+07	1.72E+07
Dispose	3.84E+08	3.58E+07	1.96E+08	1.83E+07
LANL				
Incinerate	3.62E+07	4.32E+06	2.08E+07	2.48E+06
Stabilize	2.32E+07	2.04E+07	1.31E+07	1.15E+07
Supercompact	4.56E+07	1.38E+07	2.30E+07	6.97E+06
Size Reduce	1.13E+08	3.48E+07	7.21E+07	2.21E+07
Package	1.08E+08	3.20E+07	6.42E+07	1.90E+07
Ship	9.10E+07	2.80E+07	5.40E+07	1.66E+07
Dispose	5.46E+08	5.61E+07	2.86E+08	2.28E+07
LLNL				
Incinerate	4.16E+06	2.02E+07	2.39E+06	1.16E+07
Stabilize	8.62E+06	9.04E+06	4.88E+06	5.12E+06
Supercompact	4.64E+06	---	2.34E+06	---
Size Reduce	3.92E+06	---	2.49E+06	---
Package	4.26E+06	---	2.42E+06	---
Ship	3.28E+07	1.34E+07	1.86E+07	7.60E+06
Dispose	2.19E+08	9.22E+07	1.11E+08	4.66E+07

Table G.A-1. Effect of WMin/PP on LLW Treatment and Disposal at Regional Sites-Regionalized Alternative 2—Continued

Installation/Process	No WMin/PP ($)		WMin/PP ($)	
	Operations	Construction	Operations	Construction
ORR				
Incinerate	7.93E+06	2.10E+07	4.56E+06	1.21E+07
Stabilize	2.10E+07	1.95E+07	1.19E+07	1.11E+07
Supercompact	4.33E+07	1.21E+07	2.18E+07	3.61E+06
Size Reduce	1.48E+09	3.06E+08	9.38E+08	1.94E+08
Package	4.83E+07	1.93E+07	3.04E+07	1.61E+07
Ship	3.17E+08	1.05E+08	1.20E+08	6.60E+07
Dispose	2.64E+08	6.99E+07	1.65E+08	4.37E+07
PGDP				
Incinerate	1.80E+07	2.89E+07	1.04E+07	1.66E+07
Stabilize	7.34E+06	7.17E+06	4.15E+06	4.06E+06
Supercompact	1.66E+07	3.83E+06	8.36E+06	1.93E+06
Size Reduce	5.14E+07	2.08E+07	3.26E+07	1.32E+07
Package	1.07E+08	3.14E+07	6.36E+07	1.87E+07
Ship	6.12E+07	2.05E+07	3.64E+07	1.22E+07
Dispose	2.47E+08	6.44E+07	1.27E+08	3.30E+07
Pantex				
Incinerate	---	---	---	---
Stabilize	2.95E+06	1.75E+06	1.67E+06	9.90E+05
Supercompact	1.31E+07	2.53E+06	6.62E+06	2.08E+05
Size Reduce	3.08E+08	8.16E+07	1.96E+08	5.18E+07
Package	2.53E+07	1.53E+07	1.59E+07	9.61E+06
Ship	1.04E+08	3.13E+07	6.54E+07	1.97E+07
Dispose	1.98E+08	2.08E+07	1.23E+08	1.30E+07
PORTS				
Incinerate	1.50E+07	2.59E+07	8.65E+06	1.49E+07
Stabilize	5.95E+06	5.34E+06	3.37E+06	3.02E+06
Supercompact	1.08E+07	1.26E+06	5.43E+06	6.33E+05
Size Reduce	2.22E+08	6.39E+07	1.41E+08	4.06E+07
Package	---	---	---	---
Ship	8.16E+07	2.57E+07	5.09E+07	1.60E+07
Dispose	4.02E+08	1.21E+08	2.08E+08	6.24E+07
RFETS				
Incinerate	7.15E+07	7.07E+07	4.11E+07	4.06E+07
Stabilize	3.42E+07	4.86E+07	1.93E+07	2.75E+07
Supercompact	1.09E+07	2.83E+06	5.50E+06	1.42E+06
Size Reduce	7.41E+07	4.48E+07	4.71E+07	2.84E+07
Package	4.62E+07	1.89E+07	2.74E+07	1.12E+07
Ship	4.97E+07	1.76E+07	2.94E+07	1.05E+07
Dispose	3.19E+08	3.57E+07	1.64E+08	1.84E+07

Table G.A-1. Effect of WMin/PP on LLW Treatment and Disposal at Regional Sites-Regionalized Alternative 2—Continued

Installation/Process	No WMin/PP ($)		WMin/PP ($)	
	Operations	Construction	Operations	Construction
SRS				
Incinerate	2.86E+07	3.54E+07	1.64E+07	2.03E+07
Stabilize	3.37E+07	2.44E+07	1.91E+07	1.38E+07
Supercompact	4.50E+07	---	2.27E+07	---
Size Reduce	2.86E+07	3.18E+07	1.81E+07	2.02E+07
Package	2.37E+08	8.28E+07	1.33E+08	4.65E+07
Ship	3.12E+08	1.00E+08	1.75E+08	5.63E+07
Dispose	1.95E+09	1.46E+09	9.84E+08	6.53E+08

[a] If a percentage is given, that is the percentage source reduction above which an existing facility has sufficient capacity.

Table G.A-2. Effect of WMin/PP on LLW Treatment and Disposal at Regional Sites—Regionalized Alternative 5

Installation/Process	No WMin/PP ($)		WMin/PP ($)	
	Operations	Construction	Operations	Construction
Hanford				
Incinerate	4.47E+06	2.04E+07	2.57E+06	1.17E+07
Stabilize	4.68E+06	3.53E+06	2.65E+06	2.00E+06
Supercompact	4.38E+07	6.49E+06	2.21E+07	26%
Size Reduce	2.76E+08	7.44E+07	1.75E+08	4.72E+07
Package	5.41E+07	2.03E+07	3.33E+07	1.25E+07
Ship	2.63E+08	8.67E+07	1.62E+08	5.34E+07
Dispose	2.07E+09	1.52E+09	1.13E+09	8.32E+08
INEL				
Incinerate	1.11E+08	1.16E+08	6.38E+06	6.65E+07
Stabilize	5.34E+07	6.29E+07	3.02E+07	3.56E+07
Supercompact	5.62E+07	4.11E+06	2.83E+07	10%
Size Reduce	6.28E+08	9.40E+07	3.99E+08	37%
Package	7.91E+07	2.46E+07	4.86E+07	1.51E+07
Ship	1.93E+08	6.14E+07	1.18E+08	3.77E+07
Dispose	5.62E+08	5.67E+07	2.87E+08	1.97E+07
LANL				
Disposal	4.98E+08	5.09E+07	2.75E+08	2.08E+07
NTS				
Disposal	1.95E+08	1.47E+07	9.96E+07	7.49E+06

Table G.A-2. Effect of WMin/PP on LLW Treatment and Disposal at Regional Sites-Regionalized Alternative 5—Continued

Installation/ Process	No WMin/PP ($)		WMin/PP ($)	
	Operations	Construction	Operations	Construction[a]
ORR				
Incinerate	3.02E+07	3.68E+07	1.74E+07	2.12E+07
Stabilize	2.46E+07	2.09E+07	1.39E+07	1.18E+07
Supercompact	4.59E+07	1.35E+07	2.31E+07	4.55E+06
Size Reduce	1.77E+09	3.59E+08	1.12E+09	2.28E+08
Package	4.83E+07	1.93E+07	3.04E+07	1.21E+07
Ship	3.62E+08	1.19E+08	2.28E+08	7.48E+07
Dispose	6.11E+08	1.91E+08	3.28E+08	1.03E+08
SRS				
Incinerate	6.72E+07	6.73E+07	3.87E+06	3.87E+07
Stabilize	5.01E+07	5.66E+07	2.83E+06	3.20E+07
Supercompact	4.37E+07	---	2.31E+07	---
Size Reduce	1.06E+08	6.43E+07	6.73E+07	4.08E+07
Package	2.60E+08	1.32E+08	1.52E+08	7.71E+07
Ship	3.13E+08	1.05E+08	1.83E+08	6.12E+07
Dispose	1.98E+09	1.46E+09	1.00E+09	6.53E+08

[a] If a percentage is given, that is the percentage source reduction above which an existing facility has sufficient capacity.

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Appendix H

Technology Development

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

August 1995

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APPENDIX H
Technology Development

H.1 Introduction

This appendix addresses the potential impact of technology development on the Waste Management Alternatives described in Chapter 3 of the Waste Management Programmatic Environmental Impact Statement (WM PEIS). This discussion outlines the approach taken by the Department of Energy's (DOE's) Office of Environmental Management (EM) through its Office of Technology Development and discusses selected examples of emerging technologies that may influence the WM PEIS Alternatives or mitigate the impact of EM activities.

The Office of Technology Development is responsible for managing an aggressive national program of applied research, development, demonstration, testing, and evaluation for environmental cleanup, waste management, and related technologies. This Technology Development (TD) Program undertakes a focused problem-oriented approach to have technologies available for use to support the DOE's environmental management needs in a manner that also supports the DOE's industrial competitiveness goals. The TD Program is designed to resolve major technical issues, to rapidly advance beyond current technologies for waste management operations, and to expedite compliance with applicable environmental laws and regulations. The underlying strategy is to identify and develop high-payoff waste management technologies that can: (1) cleanup the inventory of DOE nuclear component manufacturing sites and (2) better manage DOE-generated waste than is possible with existing environmental cleanup technologies. In many cases, the development of new technologies presents the best hope for ensuring a substantial reduction in risk to the environment and improved safety for workers and the public within realistic financial constraints.

The availability, and the projected availability, of appropriate technologies govern what can be cleaned up, how, and how soon. DOE's objective is to manage its waste with the greatest effectiveness, efficiency, and lowest tolerable risks to people (health, safety, jobs) and the environment. Although emerging technologies are discussed in the context of the WM PEIS, they will likely play their most prominent role in the National Environmental Policy Act (NEPA) process during remediation at individual sites or during the decision-making process of facility design and selection. This is the point at which candidate technologies would receive specific consideration. To date, thirty-nine technologies developed and demonstrated by the

Office of Technology Development have been either implemented or selected for implementation by DOE sites. Many of these technologies have been transferred to industry and are commercially available. Many more are in various stages of demonstration needed to become viable candidates for implementation. Past accomplishments in technology development are detailed in a series of Annual Reports to Congress required under Public Law 101-189.

The technologies postulated by DOE for use in waste management applications for the purpose of estimating attributes associated with the various WM PEIS Alternatives are ones which have already been widely approved by regulators. On the other hand, the technologies discussed in this Appendix, while believed to be sound in theory, require significant development before they would be considered proven, demonstrated, and generally acceptable to regulators. Emerging technologies must meet at least one, and preferably all, criteria for being "better, faster, safer, cheaper" than the current baseline technologies that they may supplant. Representative emerging technologies, if available for wide application, are considered in this appendix to help determine whether they might alter the selection of WM PEIS Alternatives. Consideration is also given to the potential ability of technology development to mitigate the environmental and economic costs of the EM program.

H.2 Focus Areas and Cross-Cutting Activities

The EM Office of Technology Development is organized on the basis of focus areas and cross-cutting activities. Five major remediation and waste management focus areas have been identified and targeted for action on the basis of risk, prevalence, or need for technology development to meet environmental requirements and regulations: contaminant plume containment and remediation; mixed waste characterization, treatment, and disposal; high-level waste tank remediation; landfill stabilization; and facility transitioning, decommissioning, and final disposition.

Contaminant Plume Containment and Remediation. This focus area deals with uncontained hazardous and radioactive contaminants in soil and groundwater. At most sites, information about contaminant distribution and concentration is insufficient. Moreover, many characterization, containment, and treatment technologies are ineffective or too costly to use. Improvements are being sought in characterization and data interpretation methods, containment systems, and in situ treatment.

Mixed Waste Characterization, Treatment, and Disposal. This focus area addresses major technical challenges to managing low-level mixed waste. Disposal capacity for mixed waste is expensive and severely limited; DOE now spends millions of dollars each year to store mixed waste because of the unavailability of accepted treatment technology and disposal capacity. Currently available waste management practices require extensive, and therefore expensive, waste characterization before disposal. Consequently, DOE must pursue technology that leads to better and less expensive characterization, retrieval, handling, and treatment and disposal of mixed waste.

High-Level Waste Tank Remediation. This focus area is primarily concerned with deteriorating tank structures and consequent leakage of their contents. Research and technology development activities must concentrate on safe, reliable, cost-effective methods for characterization, retrieval, treatment, and final disposal of high-level tank wastes.

Landfill Stabilization. This focus area addresses the significant remediation challenges posed by numerous DOE landfills. Some existing landfills have contaminants that are migrating, thus requiring interim containment before final remediation. Materials buried in "retrievable" storage pose another problem—retrieval systems that reduce worker exposure and reduce the quantity of secondary waste must be developed. Development of in situ methods for containment and treatment is also a high- priority need.

Facility Transitioning, Decommissioning, and Final Disposition. This focus area addresses the technological problems associated with the numerous weapons complex facilities no longer needed because of age or changing national security requirements. While the building and scrap materials at the facilities are a potential resource with significant economic value, current regulations lack clear release standards. The recovery, recycling, or reuse of these resources can be encouraged by enhanced technological developments for their decontamination. In addition, material removal, handling, and processing technologies must be improved to enhance worker safety and to reduce cost.

In addition to these five focus areas, the Office of Technology Development is concerned with three cross-cutting activities: *characterization*, *efficient separations*, and *robotics*. The objective of these cross-cutting activities is to provide needed technologies, in a timely, cost-effective manner, to support waste management, environmental restoration, and facility transition and management missions.

The remainder of this appendix contains a discussion of several emerging technologies. Section H.3 discusses emerging treatment and airborne monitoring technologies for waste management, with example technologies for managing low-level mixed waste, particularly the organic components of such waste. Section H.4 is an analogous discussion of emerging technologies particularly relevant to characterization and environmental remediation issues, with emphasis on their impacts on groundwater and soil contamination. The technology discussed in Section H.4 is relevant to this PEIS to the extent to which it increases (that is, by making remediation technically and economically feasible at additional DOE sites) or decreases (that is, by enabling in situ cleanup of soil and groundwater sites) the volume of waste to be transferred to the EM Office of Waste Management for treatment and disposal. Section H.5 discusses technologies that relate to transportation risks associated with most WM PEIS Alternatives. While technologies are discussed under particular categories for convenience, the reader should note that many technologies overlap both site remediation and waste management categories.

H.3 Waste Management Technologies in Development

DOE has identified nearly 2,000 different stored mixed, high-level, transuranic, or low-level waste streams at more than 50 of its sites. The Office of Technology Development has undertaken a systematic approach to solving key problems in waste management (and environmental restoration) by conducting technology development in the categories of characterization and monitoring, retrieval, treatment, and stabilization in a form suitable for final disposal. During FY 1996, the Office has planned to support the work packages shown in the Attachment to this Appendix. Waste management (as opposed to environmental restoration) efforts are being conducted most extensively in the Mixed Waste Characterization, Treatment, and Disposal Focus Area and in the crosscutting areas of characterization, robotics, and efficient separations; some other efforts (for example, pollution prevention) are also being conducted.

In this section, the technical capabilities and limitations of emerging technologies are compared with the baseline technology (usually incineration) for organic destruction in low-level mixed waste. This discussion will concentrate on the treatment of low-level mixed waste (LLMW) for several reasons: this type of waste is most broadly distributed throughout the DOE complex, at large and small sites; past practices for the storage and treatment of these wastes have led to public concerns about possible safety and health impacts; few treatment technologies have been proven for LLMW; and these are not acceptable for most of the LLMW streams. Thus, new technological advances for mixed waste treatment are widely sought.

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The organic destruction step is particularly suited for illustration because it clearly offers the potential for advances in an overall system integrating treatment, monitoring, and improved final waste forms. Technology for each of these areas is included in this discussion. The choice of organic destruction technology is also important within the framework of the WM PEIS because of the potential impacts at sites of all sizes within the DOE complex. Thus, this issue relates directly to the degree of centralization and the choice among the Alternatives analyzed in this PEIS.

H.3.1 Definition of the Issue

Most of the approximately 50 DOE sites where LLMW now exists, has existed, or is expected to exist, generate and store small volumes of LLMW. More than 99% of DOE LLMW exists at just 13 of them. Of the 50 sites, about half would require treatment of 10 cubic meters or less of LLMW per year, and several would require treatment of less than 1 cubic meter. Although much LLMW would not be suitable for incineration (for example, bulk wastes contaminated with heavy metals) the baseline technology for dealing with the organic components of these wastes is assumed for discussion purposes to be treatment using a thermal technology, such as incineration. Specific treatment categories and volumes for DOE sites are provided elsewhere in the WM PEIS.

Land disposal restrictions specifically prohibit the disposal of a wide range of waste categories into the earth (40 CFR Part 268). Prominent on the list of prohibited waste categories are organic compounds regulated under the Resource Conservation and Recovery Act (RCRA). The inventory of DOE-generated LLMW contains the regulated organics as well as substances, such as inorganics, metals, and low-level radioactive constituents.

Use of emerging technologies in treating organic mixed wastes could change the number of treatment facilities, as well as respond to concerns about the social equity of treating waste at one site shipped from elsewhere—particularly from other States or regions. Alternate thermal or nonthermal approaches to organic destruction that would make onsite treatment of small volumes more feasible could minimize these concerns and reduce the importance of organic LLMW components in decisions between centralized and decentralized treatment configurations. The degree of centralization may also be affected if similar emerging technologies, applicable at larger scales, alter the balance of costs, risks, or public acceptance of currently available technologies for treating wastes at the larger volume sites.

H.3.2 Baseline Technology

According to 40 CFR 268.42, the U.S. Environmental Protection Agency (EPA)-approved technology-based standard treatment for organic destruction is incineration; a technology that has attained this status is commonly referred to as best demonstrated available technology, or BDAT.

The schedule for availability for incineration is not a problem; the technology has been applied to the treatment of both hazardous and mixed waste. Although improvements in technique are still being made, no further development is required for using the technology at conventional fixed facilities.

The cost of incinerators is a concern. Incinerators have a relatively high initial capital cost, especially when used to treat small volumes of mixed waste. An incinerator must be designed and sized to maintain a sufficient residence time at an elevated temperature to ensure the high level of destruction necessary to meet regulatory requirements. In addition, current units are larger than the size required to treat the low volumes of waste at smaller sites. The size of the treatment unit cannot simply be reduced proportionally for smaller waste volumes; therefore, the cost per unit volume would increase as less material is treated. Because of the high capital costs for constructing fixed facilities, industry has developed mobile incinerators for hazardous waste treatment. However, no mobile systems are yet commercially available to treat DOE's mixed wastes.

Technical limitations are also a concern when applied to the DOE complex. Treatment units must be designed to accommodate a wide range of wastes with different compositions and physical characteristics. Some degree of overdesign will be necessary, resulting in a larger, more costly, and more complex system. Difficulties with segregating secondary wastes (for example, ash) may also require additional treatment and incur additional costs. Incinerators require a complex off-gas treatment system to ensure that the release of hazardous compounds will be reduced below specified or permitted levels. This problem is compounded for many DOE wastes by the presence of radionuclides. These may contaminate the off-gas stream as entrained particulates, or through volatilization resulting from the elevated temperatures required for complete combustion. The off-gas treatment system needs redundancy in design to insure appropriate levels of safety under all conditions.

Public acceptability issues are complicated by the interplay between onsite treatment and transportation. (Public acceptance is explicitly or implicitly considered by regulators under RCRA and the Comprehensive

Environmental Response, Compensation, and Liability Act (CERCLA); therefore, public acceptance strongly affects the timing for new technologies to become widely accepted and the willingness of the private sector to invest in these technologies. Consequently, judgments about acceptability are necessarily a part of an emerging technologies evaluation.) Public and stakeholder concerns about the potential for release of hazardous materials during treatment have affected the application of incineration at existing public sites and may similarly affect DOE sites. On the other hand, construction of treatment units at a site would eliminate the costs and risks associated with transportation of the wastes to other locations for treatment. These decentralized, onsite options should be favored by those stakeholders along the transportation routes, and those near the sites that would otherwise have been receivers of shipped wastes.

H.3.3 Emerging Treatment Technologies (Mixed Waste Characterization, Treatment, and Disposal Focus Area)

H.3.3.1 Introduction

This section contains a general discussion of some alternative technologies and addresses several in greater detail. Many alternative treatment technologies are being developed or demonstrated within DOE or the private sector. These include thermal treatments that destroy organic components at high temperatures and nonthermal treatments that destroy organic components at lower temperatures. Table H-1 lists specific technologies applicable to the destruction of small volumes of LLMW that were examined during preparation of this document. The list of technologies applicable to larger sites would be similar.

H.3.3.2 General

The potential advantages of the emerging technologies are compared to the baseline (incineration) using similar criteria.

Table H–1. Emerging Technologies Evaluated for Organic Destruction of LLMW at Small-Volume Sites[a]

Thermal Treatment
Plasma hearth (fixed hearth and centrifugal hearth units are commercially available)
Steam reforming
Mobile incinerators
Molten salt oxidation (MSO)
Catalytic extraction (e.g., molten metal technologies)
Reverse burn gasification (e.g., ChemChar)
Thermal reductive (e.g., ECO-Logic)
Pyrolysis
Vitrification
Nonthermal Treatments
Chemical oxidation Acid digestion Wet oxidation Wet air oxidation Wet chemical oxidation Supercritical water oxidation Catalyzed wet chemical oxidation Catalyzed acid oxidation Chemical and biological treatment
Biological treatment (both oxidative and anaerobic)
Photolytic oxidation Ultraviolet oxidation (UV), including UV—hydrogen peroxide and UV - ozone Catalyzed UV oxidation Laser-induced oxidation Photothermal detoxification unit
Electrochemical oxidation Direct (electron beam) Indirect (catalyzed electrochemical oxidation—CEO, mediated electrochemical oxidation-MEO)
Dehalogenation (e.g., potassium ethylene glycolate KPEG process)

[a] Technologies tabulated are being evaluated by either private industry or the Federal Government.

The schedule for availability for these emerging technologies *is* an issue. The alternative technologies are not developed to the point where application is guaranteed, especially within the timeframe important to selecting a programmatic Alternative. Thus, the capability of a new technology, or combination of technologies, to treat all incinerable wastes is not certain.

While some pilot-scale testing has been completed for many emerging technologies, some technologies are still being evaluated at the bench scale. Because of the limited amount of data available from the testing that has been completed, considerable technical testing is necessary before full-scale demonstrations are justified. For example, because of the difficulties and costs of handling radioactive materials, only a few tests have been carried out so far with actual mixed wastes. Most developmental efforts have used surrogates (nonradioactive materials with similar chemical or physical properties to the radioactive contaminants).

The capital cost of many of these technologies, both thermal and nonthermal, may be lower than an incinerator with similar capacity. However, because of the early stage of development, only rough cost estimates have been completed for most emerging technologies. Emerging technologies may also offer advantages in simplicity and may be more readily transported from site to site. A portable system would reduce the capital costs by avoiding the construction of multiple facilities. Another potential cost saving occurs with the reduction in characterization required for those technologies that are more "robust" than incinerators. For these cases, a wide variety of wastes can be processed without the need for extensive characterization before treatment. This would also reduce the cost for constructing complex characterization facilities at the small-volume sites and thus cut total system costs.

Technical limitations may be fewer than for incineration in the case of some of these emerging technologies; however, others may have additional limitations. Nonthermal technologies do not involve high temperature, reducing the potential for volatilization of metals and radionuclides. In addition, many of these approaches generate much lower volumes of off-gas compared to incineration. Similarly, some thermal treatment technologies under development would generate lower volumes of off-gas. Thus, a less complex off-gas treatment system may be possible. However, for some nonthermal systems, other components (such as NO_x) and secondary waste streams (such as spent reaction solutions) may also require treatment. The complexity of the total system, including secondary treatment, must be considered when comparing to the baseline. As with the baseline treatment, many emerging technologies may be designed for application in mobile units.

Public acceptability may be higher for nonthermal treatment technologies than for incineration, inasmuch as they do not bear the incineration label and may be viewed as alternatives.

The situation is further complicated by private sector market considerations. Because incineration is controversial, but is nonetheless BDAT for organic destruction of hazardous wastes, private industry is developing many alternatives to incineration to capture non-Federal markets. Much of the technology development effort has been directed toward specific waste streams found in large volume within the private sector. Only a limited amount of testing has been done to learn the range of waste types that can be treated efficiently with any particular technology. A significant amount of additional work will have to be done to show applicability, and to find acceptable processing conditions for a broader variety of waste streams, before wide market acceptance of an emerging technology is likely. Further, the emergence of a technology capable of capturing a significant share of the private sector market could lead to a sharp decline in the willingness of industry to act in partnership with DOE to continue to address DOE waste streams for which the new technology is not applicable—with adverse implications for the development of technology useful to DOE.

H.3.3.3 Specific Example: Plasma Hearth Process

The plasma hearth process (PHP) is a robust process that can treat a wide variety of wastes through exposure to plasma at temperatures greater than 3000 °C. The fixed-hearth plasma process has the potential to treat nearly all mixed waste streams present in the DOE complex, including solid combustibles, heterogeneous debris, and chemical containers. The process burns off organic components of the waste stream. The inorganic components are melted to form a glassy slag and a metal phase that can be separated and potentially recycled. Radionuclides and heavy metal contaminants are bound in the slag, which has been shown to have sufficiently low leachability to pass the EPA toxicity characteristics leach procedure (TCLP). The process includes a secondary destruction unit to ensure high organic destruction efficiency regardless of the properties of the incoming waste. Additional treatment of this secondary waste may be necessary to render the final form compliant with land disposal restriction (LDR) regulations.

The PHP can treat multiple mixed waste types contained in drums without opening them. This would greatly reduce the need for characterization of the waste before treatment and may result in a large saving in the total system cost compared with that for a less robust technology.

Schedule for availability: The plasma hearth process may be usable at one or more small-volume sites within a few years. Scaleup to larger volume applications would follow. Development of the plasma hearth process is still at the pilot scale. Tests have been carried out with several surrogate low-level mixed and TRU waste streams. An integrated nonradioactive pilot-scale demonstration system was constructed at Argonne National Laboratory-West in FY 1994, with bench-scale radioactive testing scheduled for FY 1995. The results of the demonstration on actual mixed wastes will allow a more reliable estimate of the availability of the PHP for treatment of LLMW. An integrated field-scale plasma hearth test system will be ready for operation in FY 1997. This system is expected to be similar in capacity to that required to provide treatment at the smaller DOE sites. Thus, a significant amount of information on the capabilities and any limitations of this technology will be available at the time NEPA and other regulatory decisions are made about application of technologies for treating DOE's wastes at specific sites.

Cost: Savings could occur with use of the plasma hearth process. (Estimated cost savings will be a product of the Office of Technology Development Cost/Benefit Project, an ongoing activity to establish economic parameters for technologies as a guide to setting priorities in the program and a support for technology transfer.) Baseline incineration and cementation technology requires detailed characterization and segregation of containerized heterogeneous mixed waste, followed by high-temperature incineration and cementation of the ash byproduct. PHP technology has an economic advantage over the baseline technology, with the major differences being driven by the costs of process equipment and operation, annual maintenance, and disposal. The reduced cost of process equipment is the principal factor accounting for a large cost difference over the 20-year life cycle. In PHP, pretreatment characterization requirements are reduced and the final waste form usually passes leachability requirements for final disposal.

Technical limitations: Two problem areas exist for the plasma hearth process: off-gas and materials (drum) handling. Only 1% of the air for fossil fuel burners is required for operation of the plasma torch; therefore, the volume of off-gas is much lower. The lower volume of gas is easier to monitor and control, and increases the potential for operation with a closed off-gas system, in which the release of contaminants to the atmosphere is eliminated by recycle of the off-gas. However, test results to date have shown the possibility of high levels of NO_x formation.

The plasma hearth process can be designed with a primary destruction chamber that is relatively small (e.g., contains a single 55-gallon drum of waste at a time) or scalable to accommodate multiple drums. Thus, it is applicable to small-volume DOE sites, either as fixed or mobile units. However, design issues

do arise in handling drums of waste with the plasma torch before and after treatment. For example, the inorganic slag produced will initially be at a high temperature. The temperature complicates the process of moving the slag into waste drums for disposal without compromising the integrity of the drums.

Public acceptability: The public acceptability of this process is unknown. Although the plasma hearth process involves high temperatures, the low volume of off-gas may minimize fears about the release of hazardous substances. In addition, the low thermal mass of the system would allow rapid shutdown in case of a process upset. This attribute should also be viewed favorably.

H.3.3.4 Specific Example: Catalytic Wet Chemical Oxidation

Wet chemical oxidation systems use the reaction of oxygen, or an alternative oxidizing agent, to destroy the organic constituents of a waste in an aqueous solution. In catalytic wet chemical oxidation, one or more chemical species are added to increase the rate at which the oxidation reactions progress. The example catalytic wet chemical oxidation system being developed by Delphi Research, Inc. (DETOX), uses an iron catalyst and a co-catalyst to degrade the organic contaminants in a strong acid solution. The system operates at temperatures much below those used in incineration and at moderate pressures. The expected operating conditions are approximately 150 °F and 70 psi.

Schedule for availability: The DETOX system is at an early stage of development, with testing still at the bench scale. Because design of a portable system is under way, application to wastes at small sites may be possible within 3 to 5 years. However, because of the early stage of development, a high degree of uncertainty remains about issues associated with the technology.

Cost: Catalytic wet chemical oxidation uses equipment typical of that used in chemical processing operations. A system could be constructed at a scale appropriate for treatment of the wastes at the small-volume sites or scaled up. Because the equipment is readily available, development costs should not be an impediment to commercialization. However, because development is still in the early stages, equipment and treatment costs have not yet been determined. The processing required for spent reaction acid solutions and for stabilization and disposal would add to the cost.

Technical limitations: The DETOX technology has been demonstrated at bench scale, with destruction efficiencies of 99.9999% achieved for liquid hydrocarbons, including some chlorinated organics. Successful treatment has also been demonstrated for solid combustibles and for contaminated soils. However, only a limited amount of data is available. Treatment of materials that volatilize from the reactor will require further study even though off-gas volume will be small. Because of the strongly acidic nature of the reaction mixture, engineering development is focused on construction materials, along with scale-up problems. Other technical problems include treatment of the spent reaction solutions and system integration.

A potentially mobile DETOX system is being developed by Delphi Research, Inc., along with the Los Alamos National Laboratory. Decontamination and permitting considerations will have to be addressed.

Public acceptability: As stated above, catalytic wet chemical oxidation is a nonthermal technology that operates at moderate temperature and slightly elevated pressure. Although the technology should not suffer from the incineration stigma, achieving public acceptability will likely require educating the public.

H.3.3.5 Specific Example: Vitrification

Vitrification of wastes into glass is an alternative to incineration, as well as a stabilization technology for incinerator secondary waste. Wastes and glass additives are combined and melted in a refractory furnace at approximately 1100 °C. Organic components and liquids are destroyed while radionuclides and metals are entrapped in a glass final waste form.

A broad range of waste, such as organic liquids, wet solids, dry solids, and heterogeneous solids, can be processed in a glass melter. Contaminants are chemically bound into the glass rather than simply encapsulated in the material. This will lead to improved leachability resistance over grout. Long-term stability is being evaluated as part of the technology development efforts. The stability of glass waste forms is higher than that for cement-based waste forms. Initial studies show the leachability results of low-level waste vitrification to be comparable to high-level waste glass standards. The glass reduces waste volume by at least 30% and meets land disposal restrictions. Minimal volatilization of most metals occurs because of the oxidizing atmosphere that allows wastes to form oxides and stay in the glass phase. Employing

appropriate melter technology, such as a cold top unit, will minimize volatilization of other metals, such as mercury, by causing condensation on the cap.

Schedule for availability: Waste vitrification is the selected waste form process for high-level waste at DOE's Savannah River Site near Aiken, South Carolina. The Defense Waste Processing Facility is in the final testing stage in preparation for radioactive operation in FY 1996. Vitrification of mixed waste inorganic sludge has been demonstrated at the Rocky Flats Environmental Technology Site (RFETS) using microwave energy. Further technology development of low-level waste vitrification for higher waste loading and for organic destruction will incorporate experience gained from high-level waste solidification.

Cost: Oxide raw materials for glass are inexpensive. However, melting equipment, energy required for melting, and off-gas requirements may be more expensive than incineration. The volume reduction of at least 30% for waste vitrification translates into a large cost savings in disposal. The Minimum Additive Waste Stabilization (MAWS) concept of combining waste streams and using waste materials as the glass additive is also being developed by DOE. This would decrease costs in two ways—by further reducing volume and by decreasing the cost of additives.

Technical limitations: One important concern remaining to be addressed for organic destruction application is a potential problem with glass integrity because of concentration sensitivity for carbon, some radionculides (e.g., uranium), and some hazardous metals. This integrity concern may prove to be a stumbling block for this application. Vitrification is expected to have other important applications in DOE remediation and waste management where these materials are not present in the streams. Applications may include environmental restoration wastes, decontamination and decommissioning wastes, and incinerator ash.

Public acceptability: Public confidence should be high considering that high-level waste vitrification will be established and accepted because of success at the Savannah River facility.

H.3.4 Emerging Air Monitoring Technologies

Progressive monitoring technologies are not treatment technologies like those listed in Table H-1, but may be a key factor in enhancing public acceptance of currently available and advanced waste treatment and

organic destruction technologies. The baseline monitoring methodology involves periodic sample collection of process emissions, transferring samples to a laboratory instrument, and analysis. Advanced air monitoring technologies would allow improved and real-time evaluation of the effectiveness of toxic compound destruction during treatment of mixed waste, thereby contributing to the safety and acceptability of current and advanced treatment technologies.

The primary technical limitation of current methods is the inability to conduct real-time monitoring of certain species. Online analysis of the incinerator effluent would satisfy the requirements of the Clean Air Act (CAA) while simultaneously addressing public concern over waste incineration. Public acceptance of any waste treatment depends heavily on the ability of sensors to monitor the effectiveness of the treatment and to demonstrate that effluent streams do not contribute to worker and public risk exposure. The sensors need to be integrated with control systems and safety procedures to ensure that, if effluent levels exceed their limits, contaminants are controlled in a manner that prevents their entry into the environment.

Several technologies are emerging with the potential to effectively monitor important waste treatment parameters, such as those that measure incinerator performance. These new, real-time, continuous emission monitoring (CEM) technologies would be significantly cheaper than currently required monitoring techniques. Real-time monitoring makes it possible to perform diagnostic control of feed materials to help maintain necessary incinerator operating parameters and to allow process control of gaseous effluents containing unacceptably high levels of contaminants before release. Continuous monitoring will directly address issues of environmental safety, and the technology can be used to identify and quantify organic chemicals in the air. Thus, a continuous monitor directly addresses some public concerns about thermal treatment systems.

Typical examples of these new technologies should be available for demonstration in 1 to 5 years. The schedule is controlled by technical and regulatory acceptance concerns that can only be satisfied by testing.

Fourier transform infrared (FTIR) monitoring is one emerging technology that has already undergone testing on the Toxic Substances Control Act (TSCA) incinerator at Oak Ridge. FTIR is a mathematical method that allows for spectroscopic signal averaging to significantly improve signal-to-noise ratios and improve levels of detection of organic and selected inorganic molecular stack emissions. FTIR is not a new technique, but advances in instrument design allow its use in association with in situ devices. FTIR is thus

beneficial for generating rapid results while dramatically reducing the problem of spectral interference, or failure to differentiate between different chemical species.

In an indication of potential regulatory acceptance, EPA has facilitated these tests by issuing a protocol for an FTIR continuous emission monitor to ensure that the data that the technology can obtain will be compliant. The method can readily be extended to cover thermal treatment, stack, and ambient air monitoring.

Techniques for continuous emission monitoring of elements (for example, heavy metals and radionuclides) has not yet gone through a similar protocol/data verification process. Laser-induced breakdown spectroscopy (LIBS) is one such technology. In LIBS, laser light is focused on a specific region to vaporize a small amount of material. The vaporized material forms a short-lived plasma, which emits light that is collected, dispersed, and analyzed. Elements targeted specifically are among those of primary concern at many DOE and industrial waste sites—chromium, lead, arsenic, selenium, antimony, cadmium, zirconium, uranium, beryllium, and thorium. Technical issues that must still be addressed include: (1) determining possible spectral interferences; and (2) understanding detection limits, sensitivities, and precisions of the best spectral line or lines to be analyzed. Both issues must be resolved before LIBS can achieve regulatory acceptance.

FTIR development will soon be completed and the LIBS system is scheduled to be demonstrated in FY 1995. Other developmental technologies, such as a real-time monitor for airborne alpha emissions, a continuous monitor for total, elemental and speciated mercury, and a dual mass spectrometer for simultaneous gaseous and particulate characterization and monitoring are progressing through prototype development, demonstration, and testing, with completion by the end of FY 1995.

These monitoring technology advances are not expected, by themselves, to alter the ranking of the WM PEIS waste management configuration Alternatives, but they may mitigate public concerns about air quality for whichever configuration is adopted.

H.3.5 Conclusions About Emerging Technologies for Waste Management

Emerging technologies exist that should enhance waste treatment at many small sites. Some of these emerging technologies offer the potential to be:

- Less costly than those using fixed incineration
- Technically suited for the treatment of small volumes of waste
- Transportable, if permitting and decontamination requirements are resolved
- Ready for application in a timeframe compatible with the requirements for key policy decisions at individual sites
- More readily acceptable to the public and other stakeholders

The plasma hearth process, catalytic chemical oxidation, and vitrification appear to have the potential to treat mixed waste streams at many of the smaller sites; however, neither the successful development of the necessary technologies nor their application to all waste streams at DOE's smaller sites are certain within the timeframe for formulating policy decisions. The difficulty of organic destruction argues against treatment of all DOE mixed wastes at all small-volume sites.

The emerging technologies discussed in this section may also be suitable for large-scale applications and may affect decisions on the overall waste treatment configuration. Private sector development directed toward larger scale organic destruction applications is also active because of non-DOE markets. Although not directed toward small DOE sites, the pilot-scale versions of private sector technologies might be adaptable at such sites on a case-by-case basis, if the developers see such adaptation as closely tied to eventual commercialization at larger scales.

Emerging air monitoring technologies will also enhance the acceptance of current and advanced treatment technologies; this may have the greatest impact at large-volume treatment sites, but should be viewed primarily as a mitigation measure rather than one that affects configuration selection.

H.4 Restoration Technologies in Development

The environmental restoration of DOE sites and facilities will likely affect groundwater and soil. The restoration waste loads identified as part of the sensitivity analysis in this PEIS assume reliance on land use restrictions rather than remediation to handle certain exposure pathways. A rationale for such restrictions is that applying currently available (baseline) technology to the treatment of large volumes of soil or groundwater imposes excessive time, cost, and risk (to workers and transportation) penalties. This section describes several emerging characterization and treatment technologies, and addresses their potential impacts. Their potential to mitigate the cost of implementing baseline Environmental Restoration Program technologies is also discussed. Emerging technologies could also have a significant impact on other restoration problems not specifically addressed here.

Groundwater remediation is particularly important because due to relative volumes involved, it is more costly than soil remediation and would allow greater potential for cost savings from the application of new and emerging technology. However, as discussed below, new approaches to groundwater remediation increasingly recognize that the behavior of the solid matrix above and surrounding the groundwater is critical to a technology's success or failure.

The Office of Technology Development's efforts affecting soil and groundwater are conducted principally in two focus areas (Landfill Stabilization Focus Area and Contaminant Plume Containment and Remediation Focus Area), as well as in two cross-cutting areas—characterization and robotics.

H.4.1 Definition of Key Analysis Issues

H.4.1.1 Contaminated Groundwater

Conventional technology cannot successfully treat the groundwater contamination occurring at some DOE sites to levels that would allow unrestricted access after remediation—particularly where the contaminant plume is large. Any emerging technology that radically increases the feasibility of treating groundwater to acceptable levels would lessen the need to restrict land use. Furthermore, even if cleanup levels consistent with such restrictions were adopted, but not envisioned as necessarily permanent (in effect,

adopting a policy of taking interim actions and delaying cleanup while awaiting a new technology), the timing of technology emergence would determine when the restrictions would ultimately be lifted.

Groundwater contaminant plumes at DOE sites include volatile organic compounds (VOCs), such as carbon tetrachloride, trichloroethylene, and tetrachloroethylene; semivolatile organics, such as petroleum oil and polynuclear aromatics (PNAs), pesticides, and polychlorinated biphenyls (PCBs); heavy metals, such as chromium, lead, and mercury; toxic inorganic salts, such as nitrates; and radionuclides, such as uranium, transuranics, and tritium. Although most radioactive substances are inorganics and often can be treated similarly to other heavy metal extraction processes (with regard for the special problems of radioactivity), unique treatments are sometimes required for the lower molecular weight species of cesium, strontium, and tritium.

In addition to the contaminants in the plume, contaminants are adsorbed onto the aquifer matrix material and referred to as "secondary contamination." Low water solubility organics adsorb to natural organic matter in the aquifer matrix, and positively charged ions (cations) of inorganic contaminants (for example, heavy metal and radionuclide cations) adsorb by ion exchange to the surface of clays or natural organic matter. When the plume is remediated and replaced by clean groundwater, the secondary contamination recontaminates the plume; this source may continue to release contaminants long after the primary source and the original plume have been remediated, thereby extending the life of the contamination plume. A means is needed to destroy secondary contamination in place, or to accelerate the desorption/exchange of the contaminants back into the groundwater. Thus, full cleanup of contaminated groundwater requires removal of the primary source (if it has not been completely depleted in generating the plume), removal of the plume itself, and removal of the secondary contamination.

Dense, nonaqueous phase liquids (DNAPLs) are contamination sources that are difficult to locate or remove. DNAPLs flow downward through the surface soil and vadose zone to the water table; because they are denser than water, they can continue to sink into the aquifer until they reach an impermeable zone. Many DOE groundwater contaminants are potential DNAPLs, including PCBs, mercury, trichloroethylene, and tetrachloroethylene.

Small volumes of DNAPLs can give rise to large groundwater plumes having concentrations far above acceptable health-based levels. DNAPL pools, which may be hidden in weathered bedrock layers or dead-end fractures in bedrock, can continue to diffuse back into the aquifer gradually over prolonged

periods. They may take 50 to 100 years or more to disappear through natural dissolution in groundwater. Because locating DNAPLs is so difficult, attempting to use conventional excavation methods for DNAPL removal may result in disturbance rather than recovery and can cause DNAPL migration to deeper positions in the subsurface.

Water-insoluble liquids that are less dense than water are called "light non-aqueous phase liquids" or LNAPLs. Refined petroleum fuels and oils can be LNAPLs, which are another source of contaminant plumes. LNAPLs tend to be more easily detected than DNAPLs and are thus more easily remediated. They tend to float on the water table and spread within the vadose zone. If present, LNAPLs tend to be readily collected with groundwater samples and during pumping of groundwater, and are seen as a separate phase floating on top of the water samples. Thus, LNAPLs are not nearly the special detection and removal problem that DNAPLs are, and will not be considered in detail in this discussion.

H.4.1.2 Contaminated Soils

A wide variety of soil types are present at DOE sites, including desert and humid climate soils, shallow and deep soils, permeable (sandy) and impermeable (clayey) soils, homogeneous and heterogeneous size mixes, and true soils and weathered bedrock (pre-soils). In general, common usage of the term "soil" (the correct geologic term is "overburden") includes all of the non-coherent subsurface matrix above the water table. The large volumes of soil requiring remediation at DOE sites imply that the risk to the public and to workers from handling so much soil, treating it, and transporting it to treatment facilities would be substantial. Emerging soil remediation technologies that would radically alter the need for handling and transport would also radically alter these estimated risks and capacity of required WM facilities.

The soil contaminants at DOE sites include the same VOCs, semivolatile organics, inorganics, and radionuclides found in groundwater (which is usually contaminated by soil-borne contamination). Because of the inherent affinity of many inorganic contaminants to adsorb on soil and subsurface minerals, and the low solubility and resultant accumulation of organics in the subsurface (which is enhanced immensely if the soil contains any natural organic matter), the solid matrix of the saturated and unsaturated zones can contain far more contamination than the water. Remediation attempts that approach the water alone are either destined for failure or extremely long-term programs.

The type of soil remediation technology that can greatly reduce the risks of excavation and treatment on the surface (or disposal in an engineered and approved facility) is remediation in the actual zone of contamination, that is, in situ remediation. In situ biological treatment is an available technology in need of significant refinement. In situ chemical, thermal, and electrokinetic treatment technologies are being developed. Depending on the extent to which these technologies can be developed and implemented, future soil remediation should become considerably safer and more effective than existing approaches.

H.4.1.3 The Role of Characterization

The ability to remediate all DOE facilities to current Applicable, Relevant, and Appropriate Requirements (ARARs), and to remediate many contamination sites to ARARs in a timely and cost-effective manner, is partly limited by the inability to characterize wastes effectively; that is, to identify locations and boundaries of the contaminated region and to identify the level and kind of contaminants present at the start and the conclusion of cleanup.

Inefficient characterization also increases worker risk, because of exposures during the characterization process and during actual remediation. Within the Office of Technology Development, characterization programs are given specialized, cross-cutting, technology development emphasis. Consideration involves not only environmental restoration needs, but also those associated with waste management and facility transition; the former will be emphasized in this section. Analogous "monitoring" technologies directly relevant to waste management are discussed in Section H.3.4 of this appendix.

The scope of characterization, monitoring, and sensor technology consideration includes:

- Initial location and characterization of wastes and waste environments (for example, transport and fate) before treatment

- Monitoring of waste retrieval, remediation, and treatment processes

- Characterization of the composition of final waste treatment forms to evaluate the performance of waste treatment processes

- Site closure and compliance monitoring

H.4.2 Baseline Remediation Technologies

H.4.2.1 Baseline Groundwater Remediation

The most commonly used baseline technology for plume remediation is pumping the groundwater to the surface through an extraction well, followed by treatment above ground. For organics, treatment might involve air stripping, biological treatment, or oxidation; for inorganics, treatments might involve ion exchange, oxidation, or precipitation. If the groundwater were accompanied by a LNAPL phase, an oil/water separation would be performed before further conventional treatment.

In general, ex situ groundwater treatment technologies exist for almost any conceivable situation. Remediating contaminated groundwater with these technologies, however, often provides inadequate removal of secondary adsorbed organic or inorganic contaminants (both hazardous and radioactive) from the aquifer matrix during extraction pumping. Furthermore, if the source was a DNAPL, then remediation of groundwater by conventional pump-and-treat methods is usually effective only for remediating the existing plume, not for removing the contamination source or the secondary contamination.

The common technology now used to remove secondary heavy metals or inorganic radionuclides contamination is pumping and treating. The rate of desorption of secondary metal contaminants depends on the aquifer matrix material's ion exchange capacity (which depends on organic matter and mineral—especially clay—content), the pH and redox potential of the groundwater, and the specific metal species. Desorption may be extremely slow if conditions are not optimal, but no technology to create optimal conditions for metal desorption is now widely accepted by regulators as effective.

Although pumping and treating groundwater is often proposed for cleaning up plumes, in relatively few cases can this be expected to achieve acceptable levels of cleanup in a reasonable period (for example, 5 to 10 years) because of inadequate solubilization of secondary contamination. Pumping and treating for 50 to 100 years may often be required to desorb secondary contaminants adequately. In situ bioremediation of organics and certain inorganics in groundwater is another currently available technology and, under appropriate conditions, it has the advantage of simultaneously treating the secondary adsorbed

contamination in the aquifer. It can be effective for volatile, semivolatile, and relatively nonvolatile organic compounds. It is not considered effective for DNAPLs still in "pool" form. Also, inadequate in situ treatment of secondary contaminants is likely to occur if:

- The organic material is only slightly water soluble (groundwater concentration would be too low to support biological activity); this tends to include many DNAPLs and most high molecular weight organics.

- The hydraulic conductivity of the aquifer is too low; in this case, the flow rate of nutrients or gases would be too low to support increased biological activity.

- The aquifer temperature is too low; here biological activity would be too weak to accomplish cleanup with microbes.

- The total amount of dissolved organics or toxic metals in the groundwater is high enough to poison the microbes.

- The destruction efficiency of the microbes for the contaminants is too low (refractory chemicals); then the contamination would remain untreated.

When in situ bioremediation is adequate for cleaning up a plume and any secondary contamination of the aquifer, it should be possible to complete the cleanup in 1 to 5 years.

A currently available groundwater remediation technology for VOCs is in situ air sparging, which will strip VOCs from the groundwater and will accelerate the removal of VOCs from the aquifer matrix as well. In situ air sparging will also strip volatile LNAPLs and DNAPLs from the subsurface. This technique is discussed further in the following section because it also applies to soils.

H.4.2.2 Baseline Soil Remediation

The most commonly used baseline technology for soil remediation is excavation followed by transport to an acceptable disposal facility. Other available technologies involve excavation and surface processing. Ex

situ soil treatment methods (specifically, waste volume reduction methods) such as separation of the contaminated soil fraction and soil washing are being used more often to reduce the volume of waste requiring land disposal. A primary baseline technology for contaminant removal applicable to oxidizable substances is incineration. Other thermal processes induce volatilization and then capture the contaminants for further treatment or disposal.

In situ treatment technologies are focusing on either immobilizing the contamination in an artificially generated rock matrix, or extracting the contamination by soil-washing. The primary immobilization technology involves solidification by chemical cementation. Depths are limited by the availability of the deep-soil mixing equipment needed. Soil washing is applicable to greater depths, but does require that the contaminant be readily mobilized by the wash fluid. Injection of solubilizing agents such as oxidants, reductants, acids, bases, or complexing substances is still an emerging technology.

In situ bioremediation can be effective for many organic compounds. However, inadequate in situ treatment of soil contaminants will occur under the same conditions described above for groundwater (insoluble contaminants, low temperatures, excessively high levels of contaminants, low hydraulic conductivity, inadequate destruction efficiency of the microbes). When in situ bioremediation is appropriate for a site, it is possible to complete the remediation in 1 to 5 years.

In situ air sparging is another currently available soil remediation technology, applicable to VOCs. This technique involves pumping air into the subsurface and sweeping out the more volatile substances. To some extent, this flushing can also enhance the volatilization of these compounds from an underlying aquifer matrix. In situ air sparging will strip volatile separated phases—LNAPLs and DNAPLs—from the subsurface. Air sparging is inefficient for semivolatile organics such as most pesticides, polychlorinated biphenyls (PCBs), and polynuclear aromatics (PNAs).

H.4.2.3 Baseline Site Characterization

Today, the general method for characterizing a site entails drilling wells or clusters of wells, based on a grid outline of the site. Samples are taken from these wells to determine the geology, hydrology, and aquifer contaminant levels. When drilling a well, a split spoon auger may be used to sequentially collect soil samples until the aquifer is reached. Then, the well is cased and a section (approximately 10 feet) is

screened to monitor the aquifer over a period of time. This procedure, when done for a specific grid pattern across the site, provides a horizontal mapping of aquifer contaminants. If a vertical profile is desired, a cluster of wells is installed at a specified point to monitor discreet levels of contaminants in the aquifer. For example, if the depth of an aquifer at a certain grid point is 50 feet, and 10-foot screens are called for by the regulators for well monitoring, then 5 wells must be drilled to analytically profile the aquifer at one grid point. Certain volatile contaminants and radioactive particles, such as gamma rays, are detectable at the surface, and certain information about the nature of the subsurface contaminants and potential exposures may be inferred. However, it is not generally possible to use that information to provide much more than guidance in planning the more detailed subsurface sampling.

The primary objective of site characterization is to map the contours of a contaminated area or contaminant plume; this mapping may be difficult if grid sample points are not well positioned along the plume contours, or if many data points indicate nondetectable contaminant levels. Further, the geological, hydrological, and chemical data are generally analyzed separately, not integrated. Thus, migration pathways and contaminant plume contours may not easily be determined.

Regulators establish protocols for the characterization program at each site, based upon data quality requirements, pre-existing knowledge of the site contaminants, hazards of known contaminants, and the particular statutes and regulations applicable to the program (for example, sites regulated under CERCLA and under RCRA within the same State may be responding to different regulators). Thus, instrumentation to be used, sampling frequency, and sample handling will not necessarily be identical across the entire DOE complex.

Samples are normally sent to an analytical laboratory where standard chemical and radiological instrumentation is used to measure contaminant identities and levels. Except under special circumstances, these laboratories typically are not on the site itself. The laboratories may be government operated, depending on the source site of the sample and suspected contaminants, but are often commercial enterprises, approved by the EPA through the Certified Laboratory Program.

Current characterization methods are expensive, time-consuming, intrusive, may give rise to new contaminant migration pathways, and can produce large quantities of secondary wastes. People collecting samples and those performing the analysis often do not communicate directly. Therefore, not all aspects

of the data may be fully understood during analysis. Furthermore, appropriate modifications in the protocol based on past analyses may be slow to reach the field.

H.4.3 Emerging Remediation Technologies (Landfill Stabilization Focus Area and Contaminant Plume Containment and Remediation Focus Area

A number of strategies and technologies for contaminated groundwater and soil characterization and remediation are emerging. These technologies promise improvements in the scope of applicability, cost effectiveness, and completion times for future cleanups that would significantly reduce environmental hazards and risk. They include technologies for better field detection and pinpointing of groundwater and soil contamination, as well as chemical and thermal technologies for improved mobilization of contaminants for extraction and treating.

H.4.3.1 Improved Techniques to Detect, Remove, and Contain Primary Groundwater Contamination Sources

The detection of concentrated primary sources of contamination, especially DNAPLs, is difficult with conventional technologies. The existence and location of DNAPLs at DOE sites may often be undetermined. The cone penetrometer, a vehicle-mounted punch-like device used for many years to characterize the engineering properties of the subsurface, has recently been adapted for sensing subsurface contamination using optic fiber sensors, and for continuous sampling of liquids or vapors without requiring removal of the penetrometer. Many punches of a cone penetrometer can be accomplished in the time and for the cost of installing a single groundwater monitoring well. The penetrometer should eventually permit detection of small pockets (0.5 cubic meters or less) of DNAPLs in situations where installing a well would likely disturb, or spread them, but not accurately determine their location.

Recent improvements in the design and use of the cone penetrometer include the ability to penetrate rocky soils—through the use of higher drive weights and stronger, larger diameter penetrometer rods—and the ability to emplace well points and tubing, which can be used for soil gas measurements. The emplacement of well points may ultimately be modified to allow vapor or groundwater recovery without the necessity of installing a well.

Improved nonintrusive detection methods are being developed that may be expected to detect shallow pockets of DNAPLs. These detection technologies include seismic, passive and active magnetic, ground-penetrating radar, and induced resistivity/polarization methods. Current development is focused on improving their sensitivities at greater depths. Ground-penetrating radar shows the most promise. At present, none of these technologies is sensitive enough to be used alone or on all sites for DNAPL characterization, but when used in combination with other techniques such as the cone penetrometer, they can result in excellent delineation of DNAPLs.

Methods for adsorbing or siphoning pockets of DNAPLs are also needed to exploit these detection advances. A continuous sampling cone penetrometer may be adapted to pump DNAPLs to the surface, but such development has not yet begun. Conventional excavation methods may be adaptable for DNAPL removal without causing deeper migration, if conducted in conjunction with precise locating of DNAPLs with a cone penetrometer or other sensing device.

Emplacing conventional slurry walls or sheet piling, or hydraulic control using down-gradient extraction wells, are methods for containing a DNAPL source that can be used once DNAPL detection technologies emerge. These temporary containment technologies would allow time for source study while DNAPL removal methods are being considered or tested, without delaying initiation of other plume remediation activities.

Development of equipment capable of locating DNAPLs accurately enough for containment will likely occur in the next 3 to 5 years, but pinpointing individual DNAPL pools precisely enough for removal may be 5 to 10 years in the future. Because DNAPLs are one of the most common sources of groundwater contamination, these advances can be expected to save decades in remediation times, and hundreds of millions of dollars as compared with the alternative of simply attempting to pump and treat as long as necessary to exhaust the DNAPL source.

H.4.3.2 Improved Techniques to Detect Soil Contaminants

Detection and characterization of contamination using conventional technology involves the use of either fixed monitoring wells or shallow soil-gas surveys. Although improvements have occurred in location, sampling, and analysis speed, significant limitations of these methods make them expensive and somewhat

unreliable. Improved techniques are under development to reduce cost and improve accuracy. These include the SEAMIST™ system and the previously discussed cone penetrometer. SEAMIST™ is an add-on to well technology that improves measurements of soil or water-borne contamination in both vertical and horizontal boreholes. The system facilitates chemical characterization and is a platform for geophysical sensors and video devices. Installation can be either temporary or permanent.

The technology uses an airtight membrane to line a conventional well or borehole. The membrane is forced into a drilled or punched well pneumatically. After emplacement, the entire hole wall is sealed, preventing ventilation of the pore space or circulation of pore water in the well. Once monitoring instruments are placed on the outer surface of the membrane, in contact with the hole wall, the membrane isolates each measurement location. High spatial resolution of the contaminant distribution is thereby possible.

Nonintrusive detection methods for contamination in groundwater are also applicable to characterization of soils. A suite of improved techniques for locating soil contamination probably will be in place in the next 3 to 5 years.

The same set of containment technologies already described for groundwater can usually be applied to soils once contaminants have been accurately located.

H.4.3.3 Improved General Site Characterization

In addition to purely "hardware" solutions, innovations that involve methodology may also be a key to characterization advances. The expedited site characterization method (ESC) is one method for rapid, less expensive, and technically superior characterization of a site's groundwater and soil. ESC, as initially conceived, deploys a highly technical, multidisciplinary team to the field. The team collects data daily, discusses and integrates the results, and then formulates a strategy for sampling and analysis for the following day's activities. While field chemical instrumentation analysis costs vary, they are generally more than five times lower than offsite laboratory costs. For example, costs associated with sample transportation are eliminated. One typically exploits this cost savings potential, and the associated time savings from field analysis, to take more field samples. In addition, field testing is facilitated by being able to relocate sampling locations rapidly, if analytical results suggest that this is desirable. The resulting improvement in resolution of the plume allows for sampling many fewer monitoring wells and more than

compensates for any differences in the quality of analyses that might occur between field and centralized laboratory settings. This dynamic approach to characterization saves time by reducing data integration and analysis turnaround times and saves money by minimizing well drilling and laboratory sample analyses. The net result is a faster and cheaper process that is arguably more accurate than conventional site characterization techniques.

The ESC has been successfully demonstrated at several U.S. Department of Agriculture sites in Nebraska and Kansas and at Bureau of Land Management landfill sites in New Mexico. Near-term tests will demonstrate the functionality and benefits of the process compared to conventional characterization methodologies and will characterize smaller sites focusing on organics, heavy metals, and radiological contaminants.

H.4.3.4 Improved Techniques to Mobilize and Remove Secondary Sources From Groundwater

In situ air sparging can remediate a plume and its secondary contamination simultaneously if the contaminants are water insoluble VOCs, such as trichloroethylene and carbon tetrachloride. If semivolatile or nonvolatile organics are present that are also water insoluble, heat can be added to enhance volatility or water solubility. The aquifer matrix can be heated with steam, as has been shown in the Office of Technology Development's Dynamic Underground Stripping Project. There, steam was used to remove spilled gasoline by a combination of heating and gas stripping in the vadose zone and in the aquifer itself. If this technique were applied to nonvolatile, slightly soluble, secondary contamination, including inorganics or organics, solubilization in the groundwater could be enhanced.

Methods for heating the vadose zone also are being tested, including radio frequency or microwave heating and multiphase joule (conductive) heating of the subsurface. The solubility of contaminants in water, and the volatility of organics, can be enhanced by such heating. These techniques may also be applicable to aquifer matrices that have been pumped down temporarily.

Solubility enhancement for secondary contaminants is more developed than heating techniques. Organic secondary contaminants may be solubilized by flushing with appropriate ionic or nonionic surfactants or with enzymes. Aqueous surfactant solutions have been effective in removing water insoluble organics from soils, and would be expected to be as effective with aquifer matrices. Various surfactants are already

approved for use on cropland as soil penetrants; inasmuch as they are also biodegradable, their use in aquifers should be considered acceptable by regulators. Enzymes are used in a variety of domestic cleaning and clothes washing materials because of their ability to degrade large organic molecules.

A wide variety of organic chelating agents (organic compounds that form soluble complexes with metal cations) can be used to solubilize heavy metals. These agents include ethylenediamine tetraacetic acid (EDTA) and citric acid. Some inorganics can be solubilized by acidic or basic buffers, or with oxidizing or reducing agents, allowing extraction. Electrokinetic techniques are being developed that would be applicable to shallow aquifers for mobilization of ionic contaminants. They would not require injection of reactive substances to promote mobility, but would use electrical fields to induce movement toward an extraction point.

The laboratory development of in situ solubilization methods, including chelation, oxidation, and reduction, is in progress. Successful application in the field will depend on general improvements that must include treatment-chemical introduction and monitoring techniques, control and mass balance of contaminants and treatment reagents in the subsurface, and obtaining and maintaining sufficient permeability of the treatment zones. These developments can probably be expected in the next 3 to 10 years and will be widely applicable for groundwater remediation. The eventual savings in remediation times and costs will likely be a full order of magnitude.

H.4.3.5 Improved Techniques to Mobilize and Remove Soil Contamination

Many of the same technologies discussed above in connection with mobilization of contamination in groundwater are also applicable to soil remediation, particularly for soils where the groundwater table extends upward to shallow depths. Successful application of these technologies will require major improvements in general subsurface operations methods, including:

- Techniques for the injection of treatment solutions
- Techniques for monitoring reactions and movement
- Techniques for subsurface hydraulic control
- Techniques to enhance and maintain adequate subsurface permeability

As in the case with groundwater, these developments can probably be expected in the next 3 to 10 years and will be widely applicable for subsurface remediation. The eventual savings in remediation times and costs will probably be a full order of magnitude.

H.4.3.6 Improved In Situ Treatment Technologies for Plumes and Secondary Sources in Groundwater

In situ treatment of a groundwater plume tends to be cheaper than pumping and treating because less groundwater must be pumped, secondary sources can be treated simultaneously, and secondary waste streams are minimized. Both in situ chemical and in situ biological remediation technologies are under development.

In situ chemical oxidation can destroy toxic organics or oxidize secondary organic contamination to the point that solubility increases and the oxidized products desorb and can be pumped to the surface for more complete ex situ treatment. The candidate oxidants are those that degrade spontaneously to nontoxic products in the environment, such as ozone and hydrogen peroxide.

In situ biodegradation recently became an available technology. Even so, technology development continues to address the significant limitations previously mentioned. Some examples are:

- For organics that are too water insoluble to desorb significantly, solubilization can be increased with surfactants or enzymes that do not harm the microbes. The desorbed contaminants can then be biodegraded in situ.

- In areas where low aquifer temperature makes the rate of biodegradation very slow, in situ heating will accelerate these rates so that bioremediation becomes practical.

- At sites where high levels of dissolved organics or toxic metals are present in the groundwater, or where the contaminants to be treated are refractory to biodegradation, microbes that can tolerate these conditions need to be developed and introduced into the subsurface. These goals are quite difficult, especially spreading microbes through the subsurface (which essentially behaves like a filter).

- In situ biodegradation may be expected to tie up nonbiodegradable contaminants only temporarily, such as heavy metals and nonmetal radionuclides. Biomass decay may also produce byproducts capable of chelating and mobilizing toxic heavy metals. Methods must be developed for assessing this problem beforehand and for controlling it.

H.4.3.7 Improved In Situ Treatment Technologies and Stabilization Technologies for Soil

In situ treatment of soil contamination, by reducing the generation of secondary waste streams, tends to be cheaper than excavation and treating. In addition to in situ immobilization technology, chemical and biological remediation technologies are under development. Many of the emerging technologies described above for groundwater and aquifer remediation may be applicable to soil and the vadose zone as well.

In situ vitrification (ISV) is one emerging treatment technology for soils. Melting of the soil minerals and subsequent cooling to an impermeable glass-like mass will immobilize many soil contaminants. During the heating process some organics will volatize; others will degrade. Any that escape the glass must be captured for treatment. The technology shows great promise for immobilization of radionuclides and for treatment of mixed wastes.

Minimum additive waste stabilization (MAWS) is a related process in which several waste streams with complementary characteristics are combined in order to take advantage of their separate characteristics. Doing so minimizes the need to add uncontaminated materials. In some cases, two merged streams can be vitrified when it would be impractical to vitrify one of the two alone. The benefit of this approach is that the final waste volume (for example, the wash residues from soil washing) is minimized because few or no additives are used and vitrification itself results in volume reduction.

In situ biodegradation technology has advanced rapidly. Development continues to address the significant limitations previously mentioned in connection with groundwater. In addition, accessibility of microbes and nutrients to the contaminants sorbed in the soil interstices needs to be improved. General techniques such as soil-fracturing may be inadequate to improve the rate of degradation through access to the soil micro-structure.

H.4.4 Conclusions About Emerging Environmental Restoration Technologies

The conventional approach to groundwater contaminant extraction (pump and treat) is suitable for only a few sites and contaminants. The regions associated with many contaminated DOE sites:

- Are in the vadose zone without water
- Have such low permeabilities that pumping cannot extract the contaminated water
- Have contaminants with low solubilities or volatility, and high soil affinities, and are difficult to mobilize

The ability to locate primary sources of contaminants effectively, especially before they move into groundwater, and to contain them at those locations is a significant part of any strategy to avoid increasing costs and risks in the future. Emerging characterization technologies can reduce the cost, time, and worker risk associated with restoring sites by minimizing sampling and well costs, by reducing the number of trips and time in the field to collect potentially unnecessary samples, and by precisely locating contaminated region boundaries to minimize the handling of uncontaminated soil or groundwater.

The potential for significant cost reductions because of the availability of these or other advanced technologies could result in regulatory decisions to undertake more extensive remediation at particular DOE sites than would otherwise be the case. These decisions could result in increasing the waste loads being delivered from environmental restoration activities to waste management. However, this waste load effect is unlikely to be important at a programmatic level for at least two decades because in situ technologies (which reduce waste loads) have greater potential for emergence and impact between now and that time. For unremediated sites, advanced characterization technologies can make it possible to monitor contaminant transport and provide confidence of the immobility of many contaminants and, therefore, minimal risk to public health.

Development of characterization and in situ treatment technologies—reducing the need to excavate material for processing onsite or for transport elsewhere for disposal—will achieve the greatest improvement in safe, cost-effective soil remediation and minimization of waste management loading. Exposure risk, remediation cost, and danger to the population, from both contaminant contact and transport hazards, are substantially

reduced through applying in situ technologies. In situ technologies are being developed and demonstrated for applications in the next 5 to 10 years. Some sites will still be recalcitrant, including those:

- With such poor hydraulic conductivity that most remediation methods would have difficult access

- Where the mix of contaminant chemistry (and subsurface interferences) limit the technology
- For which the extent of contamination, even with the best of innovative technology, would overwhelm financial resources

Although extremely difficult to remediate, situations of the first type (or others where the soil affinity makes the contaminant immobile) may pose less immediate risk. In other words, the same factors that inhibit remediant access may inhibit movement by the contaminants themselves. However, such inhibition is not reliable because of differing physical and chemical characteristics among the contaminants and remediants. Further, almost all sites will have soils that vary significantly in quality and characteristics. Accessibility to remediation injection or extraction will be patchy, and thus long-term "bleeding" of contaminants from isolated pockets of contamination will be a common problem.

These factors stress the importance of continuing research that enhances formation accessibility. This includes work to increase formation hydraulic conductivity and the ability to target, or pinpoint, the insertion of reagents and extraction of fluids. At present, the ability to manipulate groundwater flow is rudimentary. Plans for the application of any in situ technologies will hinge on significant improvements in subsurface control. Because many technologies will involve powerful reagents and microbes and their nutrients, regulatory approval will depend on presentation of proof that the remediation can be controlled and will not worsen the environmental hazard by replacing one contaminant with another.

With regard to schedule, technologies adequate for soil remediation are expected to be successfully developed during the next 5 to 10 years. Their implementation should be widespread in another 5 to 10 years as they become generally accepted by remediation managers, regulators, and other stakeholders. The large number of possible approaches provides a basis for confidence that one or more approaches will prove successful despite uncertainties that may exist about any particular approach. The extent of soil contamination problems at DOE sites and non-DOE sites also provides confidence of continued private sector interest in commercialization.

On shorter time scales, there is little indication that all or most sites that cannot be remediated by available technologies could be remediated with emerging technologies. Formation accessibility is too difficult and hydraulic control in the subsurface is insufficient to ensure the success of in situ methods. Short-term control until usable technologies are sufficiently mature, or long-term control and isolation, will be necessary to minimize risk where remediation is currently impossible.

Emerging technologies could mitigate the costs of remediation significantly. In the WM PEIS, DOE assumed a generic process that used new supplies of commercially available equipment and materials. Cost saving could result from the application of technologies discussed in this section. For example, the MAWS vitrification process could be less expensive than the generic vitrification process for certain applications, if on-site waste could be substituted for commercial oxide new material. Similarly, the use of the SEAMIST™ technology would provide better control of test wells, reducing the cost of characterization, and ultimately reducing the cost of pump and treat operations. These technologies are only a small fraction of the remediation technologies now under development within DOE, and many technologies should have numerous applications outside the DOE complex.

H.5 Transportation Technologies

Some of the waste management alternatives considered in the WM PEIS may require extensive transport of radioactive or hazardous materials on or between DOE sites. DOE's Transportation Management Division, with the EM Office of Compliance and Program Coordination, is sponsoring packaging research and development, packaging engineering and analysis, and packaging operations studies to produce a new generation of hazardous materials packaging.

H.5.1 Packaging Research and Development

Packaging research and development includes several related areas of development: development of analytical design codes, evaluation of packaging components, materials characterization, and packaging concepts.

Development of analytical methodologies design codes is the first such area. Structural analysis techniques are developed to predict packaging response accurately. Activities in this area emphasize establishing nonlinear dynamic analysis as an alternative for use in package certification. Specific activities will include investigation of acceptance criteria for inelastic analysis and benchmarking of these analysis codes. Thermal computational techniques are being improved. A better engineering description of hypothetical accident environments through use of new and existing analysis techniques and additional instrumentation is under development.

Development of analytical methodologies and design codes also includes activities to automate the analytical process. Transportation packagings are the final product of an iterative process of design, analysis, interpretation, modification, and redesign. This inherently inefficient design process can be vastly improved by automating evaluation of the structural, thermal, and shielding constraints to produce a more uniform factor of safety and thus more efficient design.

Evaluation of packaging components has already provided data on impact-limiting material and screening methods. A new constitutive plasticity model for wood stress through the crush range is being developed. Verification and refinement of a proposed crush failure theory for general triaxial stress states will be undertaken. A research and testing program for seal materials, begun in 1988, is characterizing the behavior of seal materials commonly used in radioactive material packages under normal and accident conditions, performance of the seals in non-deformed closures at both high and low temperatures, and response of seals to deformations in the closure region. A topic of particular interest to package designers is short-term closure movements that return to their initial configuration after a few milliseconds, resulting in the so-called "burp" release. Also of interest for many package types is the release of particulate materials instead of gaseous materials.

DOE currently is sponsoring work to establish the fracture mechanics methodology for ferritic materials, thereby extending the range of structural materials potentially usable for package construction.

One new concept is design of "Type B" transport packaging for plutonium and uranium that meets future regulatory requirements. The new package design uses nested cylindrical containment vessels with threaded closures and elastometic seals and a composite material overpack of metallic wire mesh and ceramic or quartz cloth insulation material.

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H.5.2 Packaging Engineering and Analysis

The packaging engineering and analysis programs involve engineering, design, analysis, and testing for packaging development. New packaging concepts emerge to meet specific programmatic requirements. Innovative packaging designs for transporting high activity liquid waste and environmental samples that need cooling during transport are under development. The Beneficial Uses Shipping System (BUSS) cask has been developed for transporting special-form cesium chloride and strontium fluoride capsules and conceptual designs have been completed for packages for offsite shipment of Hanford tank waste liquid samples, Hanford tank waste core samples, and onsite shipment of large volume wastes.

Attachment to Appendix H

Office of Technology Development
FY 1996 Budget Request Work Packages
for the Focus Areas and Crosscutting Programs (excluding Program Support, Program Direction, and Technology Integration)

Information from the Back-up to the Budget Submission
to the Office of Management and Budget, 10-10-94

Mixed Waste Focus Area

Plasma

- Prepare and conduct pilot scale demonstration of the plasma arc treatment process (including off-gas system) using non-radioactive surrogates. Determine partitioning of surrogate radionuclides.

- Conduct bench-scale testing of the plasma arc treatment process with actual radioactive mixed waste. Develop and demonstrate waste materials handling capabilities, both on the front and back ends of the treatment processes, in preparation for the field demonstration of the plasma hearth process (PHP).

- In preparation for the field-scale demonstration of the PHP system on mixed low level waste (MLLW), test a closed-loop off-gas system with appropriate process monitoring and control (continuous emission monitors and control loop electronics) hardware. Complete pilot-scale demonstration of the plasma arc process with actual radioactive mixed waste.

- Facilitate the early field implementation of the plasma hearth process.

Vitrification

- Complete compact vitrification system demonstration integrating melter, off-gas systems, etc. Evaluate and implement closed-loop off-gas systems with complete process monitoring and control systems on the compact vitrification units.

- Modify high level waste vitrification technology for the treatment of low level waste. Complete demonstration of polymer solidification for quality assurance and process control of final forms production. Perform field scale demonstrations on MLLW employing low temperature waste stabilization processes such as polymer encapsulation and phosphate-based ceramics.

Rocky Flats Compliance

- Design non-radioactive demonstration unit for catalytic wet chemical oxidation (CWCO) system. Begin fabrication of demonstration unit for CWCO process. Test new materials for reactor vessel of CWCO process. Test waste blending to improve process parameters.

- Test more complex waste forms with supercritical carbon dioxide extraction (SCDE) system. Evaluate enhancements for the SCDE system. Conduct cold demonstration of SCDE. Begin design of volatilization, Low Temperature Thermal Desorption, full-scale system.

- Continue development of microwave system. Test pelletizing process and select a drying technology. Demonstrate off-gas treatment and monitoring system. Design, fabricate and install upgraded bagless posting system. Design, fabricate and test components of break-open system. Perform non-radioactive bench-scale tests on surrogates of additional wastes. Perform tests on currently generated by-pass sludge. Perform full-scale tests on spiked surrogate wastes.

- Begin demonstration of macroencapsulation of miscellaneous waste. Conduct polymer microencapsulation demonstration on radioactive nitrate salt waste. Conduct lab-scale testing of thermal treatment process waste. Gear-up for radioactive lab-scale tests on surrogate waste of backlog sludge microencapsulation. Conduct non-radioactive demonstration on new sludges. Conduct non-radioactive bench scale tests on non-thermal treatment waste.

Supercritical Water Oxidation

- Complete non-radioactive testing and demonstration of the supercritical water oxidation (SCWO) pilot plant with DOE hazardous and surrogate mixed wastes.

- Prepare Environmental Impact Statement (EIS) and Preliminary Safety Analysis Report (PSAR) for the radioactive demonstration of the SCWO pilot plant.

- Complete conceptual design of the SCWO pilot plant for the radioactive demonstration.

Complete radioactive demonstration of the Delphi DETOX process to catalytically oxidize the organic constituents of waste streams in a contained reactor.

Develop advanced effluent control systems, continuous emission monitors, cleanable HEPA filters, and other off-gas treatment and monitoring systems.

Develop alternative low temperature treatment technologies for mixed waste, specifically for combustible contaminants.

Develop intelligent remote sensing systems and survey robots for radioactive storage areas.

Develop alternative low temperature final forms for mixed waste.

Develop processes to refine and/or enhance basic knowledge solutions for the removal of heavy metals and mixed hazardous wastes from soils; use of metal oxide particles as reagents for destruction and immobilization of hazardous substances.

Radioactive Tank Waste Remediation Focus Area

Demonstration of real-time tank integrity inspection and waste mapping technologies with the Light-Duty Utility Arm (LDUA).

- Camera Systems, Laser Range Finder, Structured Light Hardware.

- Tank Riser Interface and Confinement (TRIC) System.

- Light Duty Utility Arm Decontamination System.

- Acoustic Emission System for detection of pipeline leaks.

- Supervisory control and data acquisition system for LDUA.

Integrated testing and development of waste dislodging and conveyance tools for retrieval of multiple waste types.

- Waste Dislodging and Conveyance Hydraulic Test Bed.

- High Pressure Water Jet Scarifier.

- Medium Pressure Water Jet Scarifier.

- Further waste dislodging and conveyance work to plan retrieval operations and meet 99% retrieval minimum from TPA.

Hot cell demonstration of characterization of waste which includes the Raman spectroscopy system.

- Raman spectroscopy system.

- Further development for a higher resolution scanning Raman spectroscopy system.

- In-situ characterization, on-line monitoring of waste and data analysis methods.

Perform radioactive testing of an out-of-tank mobile evaporator

- Fabrication and radioactive testing of evaporator/concentrator Compact Processing Unit (CPU).

Conduct radioactive demonstration of a mobile, field maintainable, CPU for cesium removal.

- Complete resin and skid testing, and CPU design.

- CPU Test Unit.

- Cs extraction resin.

Demonstrate sample retrieval and on-line, in-situ waste analysis with the LDUA System in Idaho.

- LDUA adaptation for Idaho tanks and sample retrieval.

- Waste dislodging and conveyance tools adaptation for LDUA and Idaho tanks.

Hot demonstration of solid/liquid separation using cross flow filtration system.

Demonstrate low pressure waterjet tools for waste removal from tanks, leading to a radioactive retrieval demonstration at Oak Ridge/Idaho; adaption of the waste dislodging and conveyance scarifiers for Oak Ridge Gunnite tanks.

Using actual waste from the Melton Valley Storage Tank Farm, demonstrate sludge and supernatant processing of this waste.

- Demonstration of sludge dissolution and TRUEX solvent extraction for partitioning of TRU components.

- Demonstrate sorbent removal of Cs, Sr, and Tc from supernate.

- Complete sorbent testing for removal of Sr and Tc.

- Continue development of general site-specific waste processing flowsheets.

- Adaption of sludge/supernate processing system for demonstration on Hanford tank waste.

- Continue development of waste processing flowsheets.

Demonstrate in-tank equipment designed to remove scrapped hardware from waste tanks.

Analysis techniques and sensors to characterize and monitor chemical and physical conditions within tanks. Work includes spectroscopic techniques and LDUA development.

Develop end-effectors for waste dislodging and conveyance.

Develop solutions for tank waste using compact processing units.

Develop waste disposal technologies.

Refine and enhance basic knowledge solutions in the development of in-situ measurement of fissile, moisture, thermal properties, fission products, and head space gases; wide dynamic range tank hot spot identification.

Landfill Stabilization Focus Area

Containment

- Demonstrate physical barriers formed from viscous liquids (polybutene and colloidal silica) emplaced under controlled viscosity conditions.

- Evaluate two new flowable grout bentonite-mineral-water-inorganic grout techniques to reduce the cost of barrier emplacement.

- Demonstrate hydraulic and diffusion barriers in the vadose zone surrounding buried waste.

- Demonstrate surface controlled emplacement horizontal planar barriers beneath waste sites using tilt meters and models to predict effectiveness.

- Assessment of polymer cement, ion exchange cement, cement glass and latex cement grouts for vertical subsurface barrier long term effectiveness

- Demonstrate four innovative advanced landfill cover designs and compare with existing EPA designs

- Demonstrate dry barriers by using active/passive ventilation of coarse barrier layer to remove water.

- Demonstrate migration barrier covers using locally available soils/rocks and synthetic barriers.

- Demonstrate a prototype model for the selection of barrier cover systems using a decision analysis tool that analyzes tradeoffs to compare landfill cover technologies on effectiveness, risk, and cost.

Stabilization

- Perform field-scale testing of buried waste encapsulation techniques at arid site burial grounds by injecting naturally occurring cementing solutions to form soil/waste monoliths that are impervious to water migration and immobilize contaminants.

- Initiate in-situ treatment techniques for buried waste (through field testing at a full-scale cold test pit location) that establishes a vitrified glass matrix while destroying volatile organics.

- Develop other stabilization technologies (in association with industrial programs).

- Demonstrate long-term monitoring techniques and in-situ monitoring to predict failures, and assess the effectiveness of the stabilization technology using time domain reflectometry/in-situ moisture monitoring, leachate collection systems, directional well holes, plant and intruder analysis, and subsurface geophysical evaluations.

Containment and Stabilization

- Demonstrate active/passive acoustic system for the placement and monitoring of barrier technologies.

- Demonstrate electromagnetic measurement techniques for the monitoring of containment and stabilization activities.

- Demonstrate specialized borehole deployed geophysical instrumentation for the monitoring of containment and stabilization activities.

Treatment

- Conduct hot bench-scale thermal treatment tests using DC Graphite plasma furnace which can operate in the submerged or transfer arc mode.

- Conduct hot bench-scale thermal treatment test using millimeter wave radiometer to determine spatial resolution of the temperature measurements.

- Conduct hot bench-scale thermal treatment tests using microwave plasma analyzer in the offgas flow from a high temperature furnace that allows real-time assay of offgases for metals and organics.

- Conduct hot bench-scale offgas treatment tests using non-thermal electrical discharge plasma for the destruction of hazardous chemicals.

- Demonstrate batch/continuous leach technology for uranium-containing soils at Fernald.

- Demonstrate by laboratory simulation performance and economics of uranium heap leaching for comparison with batch-reactor method using transparent leaching columns.

- Demonstrate minimum additive waste stabilization at Pantex by further developing the concept of blending waste in an integrated system centered on vitrification, using the Duramelter, and also including soil washing.

- Demonstrate magnetic techniques on uranium-contaminated soils at Fernald.

- Demonstrate biphasic separation techniques on uranium-contaminated soils at Fernald.

- Demonstrate ex-situ treatment technologies for the removal of mercury from Oak Ridge Reservation.

Removal

- Initiate hot demonstration for INEL TRU waste pits using dual arm cooperative retrieval system that delivers dual manipulator capability to the dig-face and deploys various retrieval support tools.

- Initiate hot demonstration for INEL TRU waste pits using innovative end-effectors and conveyance system that achieves dust-free dumping and uses a self-guided vehicle to convey retrieved waste to a treatment facility.

- Initiate hot demonstration using dig-face characterization that uses multiple sensor data integration and interpretation for real time characterization data in support of retrieval operations.

- Initiate hot demonstration of TRU dust monitoring using laser optical scattering techniques for dust assessment and laser-induced breakdown spectroscopy for real time composition determination.

- Initiate hot demonstration of retrieval integration using a "rad hardened" teleoperated 60,000 pound class excavator with supervisory control for data transfer and collision avoidance for the integrated system.

- Demonstrate buried waste contamination control in "hot" environment using dust generation minimization hardware/procedures and implement dust/contamination control measures (misting, wetting agents, forms, vacuum).

Assessment

- Conduct hot demonstrations of Radiological Hazardous Materials Measurement System that consists of multiple measurement cells and integrates individual measurements to improve quantitative assay capability.

- Demonstrate Combined Thermal Epithermal Neutron system which uses thermal neutrons to interrogate for fissile isotopes in waste drums.

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- Demonstrate Active Passive Computed Tomography which uses a high purity germanium detector for non-destructive assay of gamma-emitting nuclides in sludge, combustibles, and metal matrices with a 55-gallon drum.

- Demonstrate Digital Radiography using a high energy x-ray source installed in a commercial scanner to measure density and non-destructively view the contents of high density drums

- Conduct Glass/Ceramic Performance Assessment to provide the necessary database and the thermodynamic/kinetic modeling capabilities to make reasonable long-term predictions regarding the performance and durability of LLW/LLMW vitreous waste forms under potential disposal site conditions.

- Conduct Glass/Ceramic Composition Envelope Study to provide a database of vitreous waste form compositions and properties plus an easy to use modelling tool using actual wastes, where available from three DOE sites, or reasonable surrogates to develop vitreous waste forms that are then tested for processability as well as durability characteristics.

- Demonstrate technologies for waste assay during waste handling operations.

Other

- R&D of advanced monitoring technologies for remediated landfills.

- Refine and enhance basic knowledge solutions in the development of methods and processes for non-intrusive and intrusive site characterization and waste assay.

- Refine and enhance basic knowledge solutions in the development of verification technologies for the emplaced barrier continuity with reduced site disruption; hot spot and full-scale retrieval of untreated waste.

- Refine and enhance basic knowledge solutions in the development of pre-, primary, and secondary ex-situ treatment and recycling secondary waste streams; subsurface contaminant technologies.

Contaminant Plume Containment and Remediation Focus Area

Reactive barriers and deep subsurface barriers.

- Demonstrate a reactive barrier for 90Sr and 137Cs at arid site.
- Demonstrate a reactive barrier for 99Tc and TCE at humid site.
- Field-scale testing of permeable barriers at humid site.
- Develop methods to emplace reactive barrier materials at depths up to 50 ft
- Develop methods to extract or rejuvenate reactive materials to prolong barrier life.
- Develop performance monitoring techniques for reactive barriers and subsurface impermeable barriers.
- Demonstrate barrier emplacement tools to create an integrated barrier/floor wall.

Develop and field test technologies for detecting/immobilizing/removing metals and radionuclides in ground water.

- Develop in-situ redox manipulation for immobilization of uranium in ground water at Hanford.
- Field test the MAG*SEP process for removal of radionuclides from ground water at Savannah River.
- Demonstrate the ex-situ biosorption of uranium process on Fernald ground water.
- Develop new methods for the removal of 99Tc from ground water.
- Demonstrate electrokinetic removal of uranium from Oak Ridge ground water at the pilot-scale.
- Demonstrate electrokinetic methods for migration and removal of heavy metals in groundwater.

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- Develop in-well removal methods (recirculating wells) for various metals.

- Field test mobile lab-based characterization methods for metals in ground water, such as laser-based spectroscopy methods.

- Demonstrate electrokinetic methods for removal of Chromium at Sandia.

Develop and field test detection, extraction, and treatment systems for DNAPLs in ground water.

- Develop and field test advanced extraction systems for DNAPLs using foam/surfactant mixtures at Paducah or Oak Ridge

- Further develop and field test extraction systems for DNAPLs, using heating methods (e.g. radio frequency heating, steam injection, ohmic heating).

- Develop and field test DNAPL degradation using aerobic/anaerobic bioremediation at Hanford.

- Develop and field test advanced DNAPL detection systems.

In-situ ground water treatment technologies for heavy metals, radionuclides and DNAPLs.

- Develop contaminant-specific ionic complexant soil flushing solutions.

- Demonstrate in-well removal methods (recirculating wells) for various metals at the Pinellas Plant.

- Demonstrate mobile lab-based characterization methods for metals in ground water, such as laser-based spectroscopy methods.

- Evaluate and demonstrate biological systems that concentrate tritium from ground water.

- Demonstrate DNAPL degradation using staged aerobic/anaerobic bioremediation at Hanford.

- Develop methods to reduce chemical contaminants (e.g. uranium and chromium) to an insoluble form using bioremediation or chemical addition to soil.

- Develop molecular diffusion and diffusion-related chemical reactions to concentrate tritium from ground water.

- Demonstrate advanced extraction systems from DNAPLs using foam/surfactant mixtures at Paducah or Oak Ridge.

Advanced remediation systems at arid sites (includes biologic and chemical treatment and characterization and sensor systems).

- Complete demonstration of Measurement-While-Drilling technology at Savannah River restoration site.

Technology for heavy metals and radionuclides to minimize secondary waste treatment and reuse treatment fluids.

- Develop chromatography columns to selectively adsorb contaminant species.

- Demonstrate MAG*SEP technology on radionuclide and heavy metal contaminated ground water at the Savannah River site.

Technology to immobilize or remove heavy metals, radionuclides and DNAPLs in soil.

- Demonstrate Chromium (VI) immobilization using gas phase reducing agents at Savannah River restoration site.

- Perform pilot-scale test of DNAPL destruction using in-situ chemical oxidation with peroxide or permanganate at Portsmouth.

- Perform pilot-scale test of electrokinetic removal of radionuclides from arid soil.

- Perform pilot-scale test of staged anaerobic/aerobic biodegradation of DNAPLs in soil.

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- Test an ex-situ process of plant uptake and concentration at the pilot-scale for radionuclide removal from ground water.

Improved subsurface access technology for difficult soil conditions.

- Enhancements of cone penetrometer technology as an assay tool for subsurface characterization.

- Develop horizontal drilling methods that can utilize existing well holes as points of origin.

- Adapt and demonstrate existing remote sensing techniques for the characterization of contaminant plumes.

Demonstrate temporary barrier systems for use with in-situ treatment systems.

In situ treatment technology for non-volatile organic compounds (PCBs, PAHs).

- Develop and demonstrate bioremediation techniques for degrading polyaromatics.

- Demonstrate methods to destroy PCBs using chemical oxidation.

In-situ remediation (stabilization, biological treatment, electrokinetic treatment, surfactant flushing, etc.), containment technologies (diffusion barriers, reactive barriers, etc.), and barrier technologies for site remediation. Contaminants of special interest are DNAPLs and chlorinated organics.

Develop characterization instruments for pre-, post-, and on-line analysis to determine type, concentration, and location of contaminants to assist site remediation activities.

- Demonstrate mobile lab-based characterization methods for metals in ground water, such as laser-based spectroscopy methods

- Demonstrate advanced extraction systems from DNAPLs using foam/surfactant mixtures at Paducah or Oak Ridge.

- Demonstrate MAG*SEP technology on radionuclide and heavy metal contaminated ground water at the Savannah River site.

On-line process control for in-situ treatment and mobile labs or on-site testing, and secondary waste minimization and recycling.

- Demonstrate mobile lab-based characterization methods for metals in ground water, such as laser-based spectroscopy methods.

- Complete demonstration of advanced VOC remediation system at Hanford, including in-situ air stripping, in-situ chemical oxidation, and/or staged aerobic/anaerobic destruction of VOCs.

Treatment of tritium in groundwater and aqueous waste streams and process data for fate and transport modeling.

Refine and enhance basic knowledge solutions in the development of characterization of subsurface contamination, modeling of contaminants under heterogenous conditions; identifying and quantifying residual NAPLs contamination in the subsurface and heavy metals in groundwater; lab to field experimentation on micro bio-organisms to analyze survivability and longevity.

Develop refinements and enhancements in basic knowledge solutions for groundwater and soils remediation of halogenated hydrocarbons; monitoring technologies for post-closure of the vadose zone; bioremediation technologies of DNAPLs.

Refine and enhance basic knowledge solutions in the development for the destruction and removal of VOCs using naturally occurring phenomena; competitive and mass transfer effects on the sorption and desorption of contaminants in soils.

- Perform pilot-scale test of staged anaerobic/aerobic biodegradation of DNAPLs in soil.

Refine and enhance basic knowledge solutions in the development of pre-, primary, and secondary ex-situ treatment and recycling secondary waste streams; subsurface contaminant technologies.

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Facility Transitioning, Decommissioning and Final Disposition Focus Area

Concrete Decontamination: demonstrate improved processes for the decontamination of surface and volumetric contaminated concrete (field pilot-scale electrokinetic process, field pilot-scale wall process, field pilot-scale coating process).

Metal Decontamination: demonstrate improved processes for the decontamination of surface and volumetric contaminated metal (field pilot-scale flushing process, field pilot-scale carbon dioxide process, field pilot-scale ultrasonic process, field pilot-scale mechanical process, field pilot-scale chemical process).

Concrete and Metal Structure Dismantlement: demonstrate improved processes for size reduction, dismantlement and containment of concrete and metal structures (field pilot-scale telescopic boom process, field pilot-scale overhead platform delivery system, field pilot-scale mobile platform delivery system, field pilot-scale size reduction end effectors, field pilot-scale dismantlement end effectors).

Metal Recycling: demonstrate improved processes for the conversion of metal with residual contamination into useful products (field pilot-scale stainless steel into waste drums and boxes, field pilot-scale slab casting process, field pilot-scale nickel into stainless steel, field pilot-scale plasma melting process).

Material Stabilization: demonstrate improved process for the stabilization of asbestos in place.

Facility Stabilization: demonstrate improved processes for the stabilization of facilities (field pilot-scale fuel pool treatment processes, field pilot-scale fuel pool characterization processes, field pilot-scale plutonium glovebox size reduction process, field pilot-scale glovebox disposition process, field pilot-scale plutonium residue handling process).

Facility Stabilization: demonstrate improved processes for the stabilization of facilities (field pilot-scale equipment disposition process, field pilot-scale equipment size reduction process, field pilot-scale equipment decontamination process, field pilot-scale equipment in process monitoring process, field pilot-scale glovebox in process monitoring system).

Material Disposition: demonstrate improved process for the disposition of depleted uranium (field pilot-scale non-metallic applications, field pilot-scale shielding application).

Develop advanced worker systems.

Develop systems for the removal of contaminated paint and other contaminants, such as grease, oil and PCBs from concrete and metal surfaces.

Develop mobile workstations for decontamination and decommissioning.

Develop recycling of radioactive contaminated scrap metal.

Develop decontamination and dismantling end effectors and plasma arc development

Sampling, imaging, and characterization systems for pre-, post-, and on-line analysis during decontamination and decommissioning.

Develop robotics for decontamination and decommissioning.

Refine and enhance basic knowledge solutions in the development of solvent and material substitution and cryogenic decontamination and cutting.

Crosscutting Programs—Characterization

Process monitors and controls for three candidate mixed waste treatment systems.

Continuous real-time air monitors.

Non-destructive remote techniques to characterize unopened waste containers and final waste forms.

Process monitors and controls for treatment techniques other than three candidate mixed waste treatment systems, (e.g. supercritical oxidation).

Detect tank leaks, head space gases (volatile and poisonous), and water content of waste tank matrices (for safety and public health issues).

Testing of tank imaging technology for retrieval operations in a radioactive environment.

Methods for less expensive and faster hot cell analysis and in-situ tank waste analysis (chemical analysis).

In-situ testing of physical properties of tank waste.

On-line process monitoring and control for tank waste retrieval, transfer, and treatment operations.

Field-deployable, real-time chemical and geophysical sensors and in-situ surface-based deployment systems to identify subsurface contaminants (DNAPLs) in support of the Expedited Site Characterization Process.

- Performance monitoring techniques for reactive barriers

- Field test mobile lab-based characterization methods for metals in ground water, such as laser-based spectroscopy methods.

- Develop and field test advanced DNAPL detection systems.

- Modify and adapt high resolution geophysical technologies to better identify contaminant plumes (e.g. DNAPLs)

- Enhance decision support and data fusion of optimal sampling. Develop additional capabilities to map subsurface contaminant plumes.

Develop large area scanning and mapping systems for detection of U and other contaminants on facility and land surfaces.

Develop non-destructive assay techniques to assay contaminants in constrained areas such as inside pipes and equipment.

Transfer airborne deployment sensors from the classified community and configure for environment applications.

Develop real-time sensor systems for decontamination of concrete surfaces to identify PCBs, uranium, plutonium, tritium, fission products, and mercury in the near-surface layer of concrete.

Develop real-time sensor systems to characterize metal scrap contaminated with 99Tc and activation products such as 60Co.

Develop continuous real-time monitors for radioactivity in liquid streams.

Crosscutting Programs—Efficient Separations

Develop/adapt radionuclide separations technologies for application to liquid mixed wastes.

Develop technologies to remove volatile species (e.g. mercury, chlorides, organics), and therefore simplify treatment of mixed wastes.

Complete development and demonstration of Cs/Sr removal technologies to meet milestones for LLW pretreatment facilities. Evaluate and integrate separations pretreatment processing schemes to meet LLW glass performance specifications.

- Develop baseline sludge treatment to determine feasibility of meeting milestones at Richland. Develop alternative sludge pretreatment technologies to ensure minimization of HLW volume.

- Accelerate sludge treatment efforts to meet FY98 Tri Party Agreement milestone at Hanford. Emphasis on hot testing of actual tank wastes to evaluate behavior and HLW volume reduction under both alkaline (baseline) and acid conditions.

- Develop technologies to remove Tc and TRU from tank waste to improve waste form performance and to meet requirements for vitrification.

Develop and adapt separations agents for cleanup of soils containing contaminants other than Pu, U (e.g. Tc, heavy metals)

Provide sorbents for incorporation into reactive barriers used for plume mitigation.

Evaluate feasibility/cost of tritium removal technology (D&D) for cleanup of groundwater.

- Perform pilot-scale test of electrokinetic removal of radionuclides from arid soil.

Demonstrate tritium removal technologies from waste storage basins.

Demonstrate improved residue treatment technology to meet Rocky Flats schedule.

Expand and adapt sludge leaching technologies to D&D of solids.

Evaluate separation need for recycle of wash liquids (D&D, soil) and process chemicals.

Crosscutting Programs—Robotics

Develop systems to automatically handle drums of mixed waste on front-end of mixed waste treatment process.

Develop robotic systems to automatically inspect stored drums of mixed waste.

Develop and demonstrate back-end materials handling system at waste treatment facility.

Develop fully functional robotic system on full scale test bed.

Develop automated analytical chemistry modules for radionuclides, metals, organics and inorganics.

Develop cooperating manipulators (dual-arm) system for D&D and Tank Waste applications.

Develop automated analytical chemistry modules for radionuclides, metals, organics and inorganics.

Develop mobile system to automatically measure and record chemical and radiological contamination on internal surfaces (e.g., walls, hot cells) of buildings.

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Appendix I

Distribution of Minority and Low-Income Populations at the 17 Major Waste Management Sites

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

August 1995

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APPENDIX I
Distribution of Minority and Low-Income Populations at the 17 Major Waste Management Sites

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 to minority and low-income populations. DOE identified and mapped the distribution of minority and low-income populations at the 17 major sites then reviewed the human health effects and environmental impacts associated with alternatives for the five waste types at those sites. This appendix presents the maps showing the distribution of minority and low-income populations at the 17 sites. Appendix C provides a description of the methods used to evaluate environmental justice impacts. Those impacts are described in the main text of the Waste Management Programmatic Environmental Impact Statement.

Demographic information obtained from the U.S. Bureau of Census was used to identify minority and low-income populations in the zone of potential impact surrounding each of the sites under consideration. This zone is defined as a circle with origin at the site center and an 80-kilometer (50-mile) radius. This 80-kilometer (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 specify 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. Transportation impacts are assessed within 800 meters (0.5 miles) of transportation routes for incident-free transportation because impacts beyond this distance are expected to be negligible. For transportation accidents, an 80-kilometer (50-mile) radius was used.

Definitions

Definitions used to develop and map the community characteristics data are as follows:

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, with 4,000 persons being ideal. 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.

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. For the purposes of this analysis, a minority populations was defined as any census tract within the 80 kilometer (50-mile) zone of impact where minority individuals comprise 50% or more of the population.

A ***low-income population*** was defined as a census tract with a median income to a family of four equal to or below the national poverty level of $12,674 (rounded to $12,700 for this analysis). Census tracts were included in the analysis if 50% of the area of the tract fell within the 80-kilometer (50-mile) radius.

Mapping Procedures

For each of the 17 major WM sites, demographic maps were prepared using 1990 census data available from the U.S. Bureau of the Census. Maps of the minority and low-income populations are shown in Appendix I. Figures I-1 through I-17 and Figures I-18 through I-34 illustrate census tract distributions for minority populations and low-income populations respectively for areas surrounding the 17 DOE sites being considered for the management of the five waste types. These maps are based on an analysis of 1990 United States Bureau of the Census Tiger Line files, which contain political boundaries and geographical features, and Summary Tape Files 3A (as processed by the U.S. Environmental Protection Agency), which contain demographic information (US DOC 1992a, b, c). Data were resolved to the census tract group level. Native American tribal lands within 80 kilometers (50 miles) of each site were also identified and mapped and are included in Appendix I, where applicable, with the minority distribution maps I-1 through I-17

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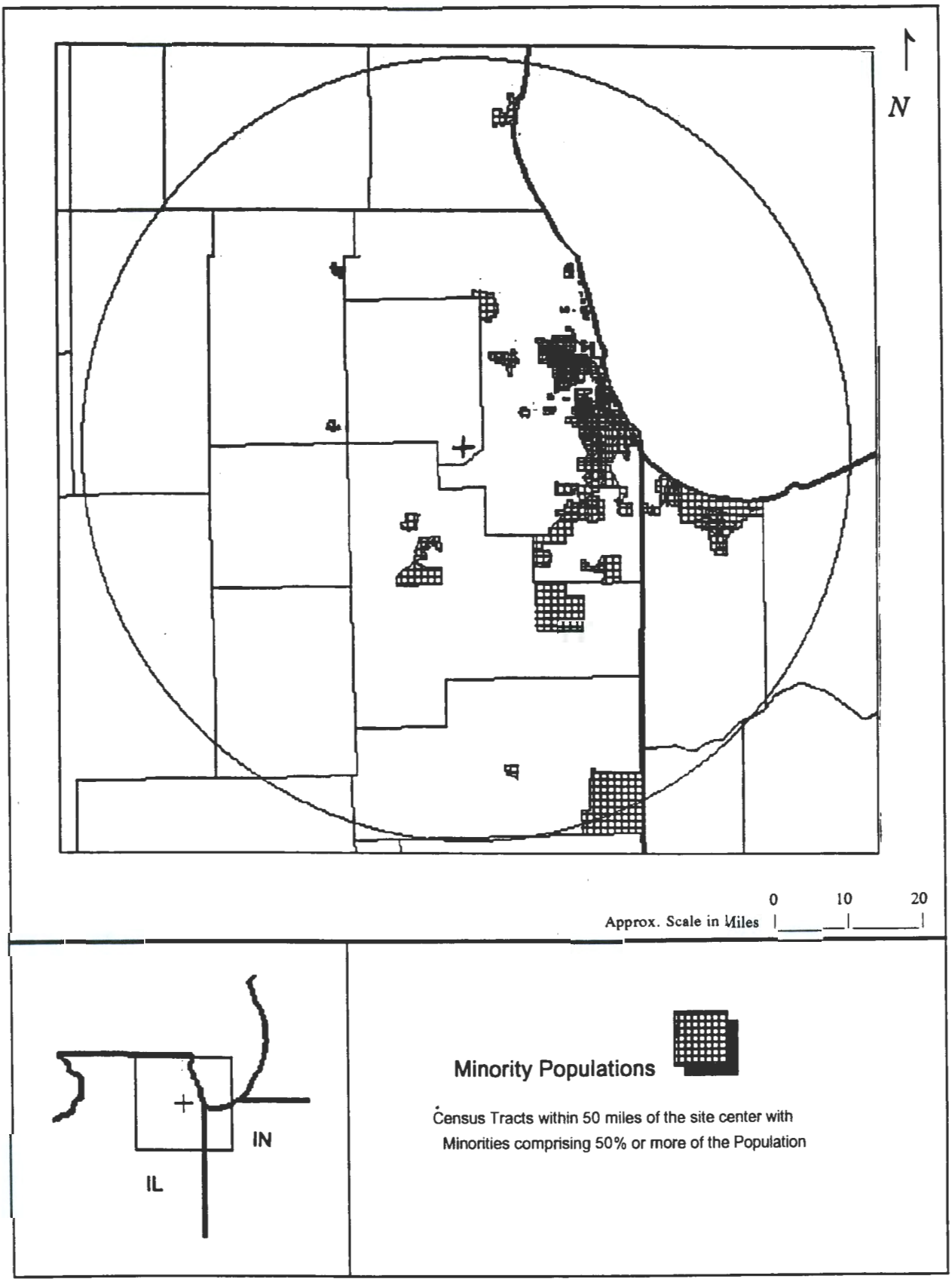

Figure I–1. Distribution of minority populations at Argonne National Laboratory-East.

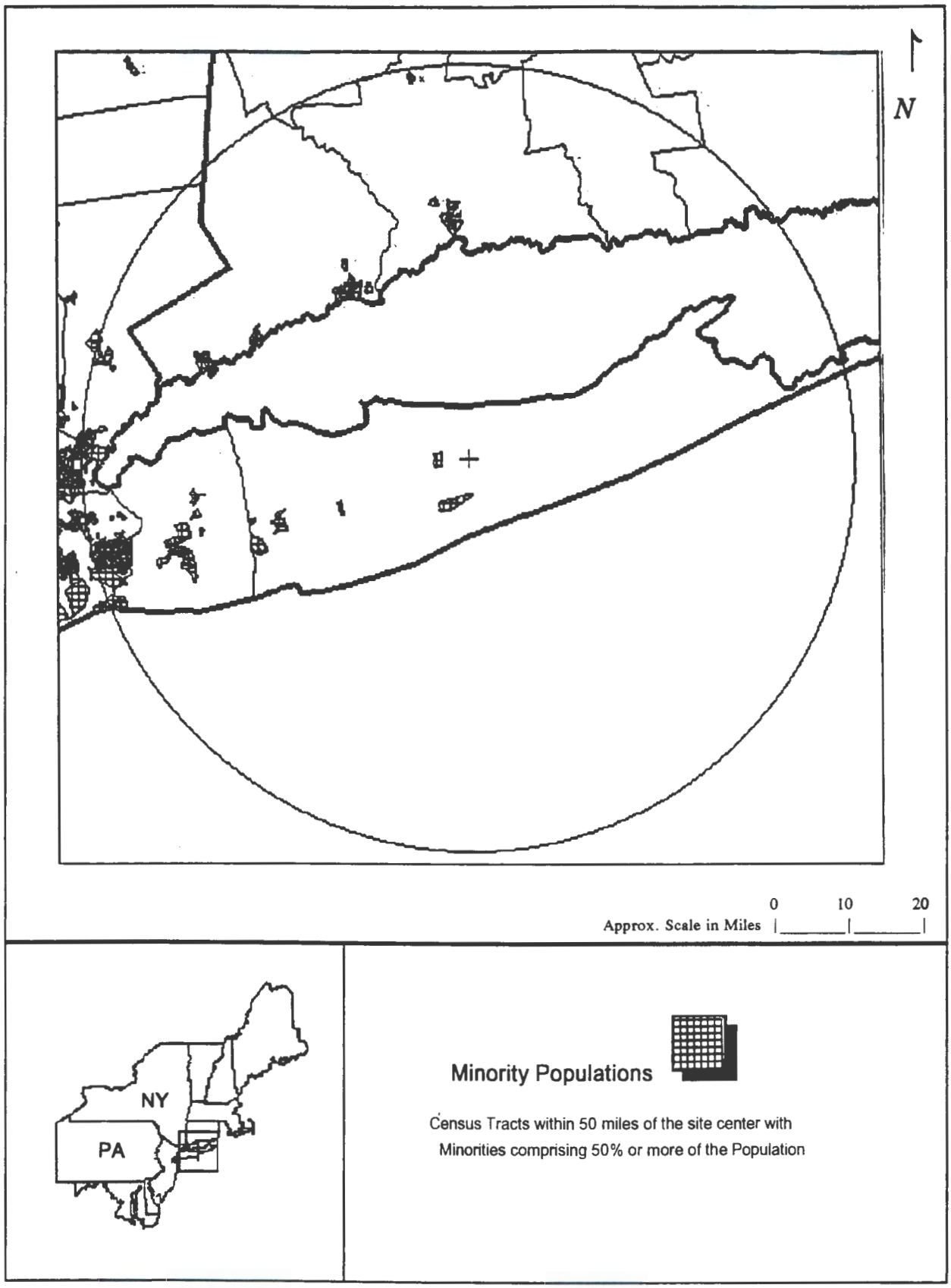

Figure I–2a. Distribution of minority populations at Brookhaven National Laboratory.

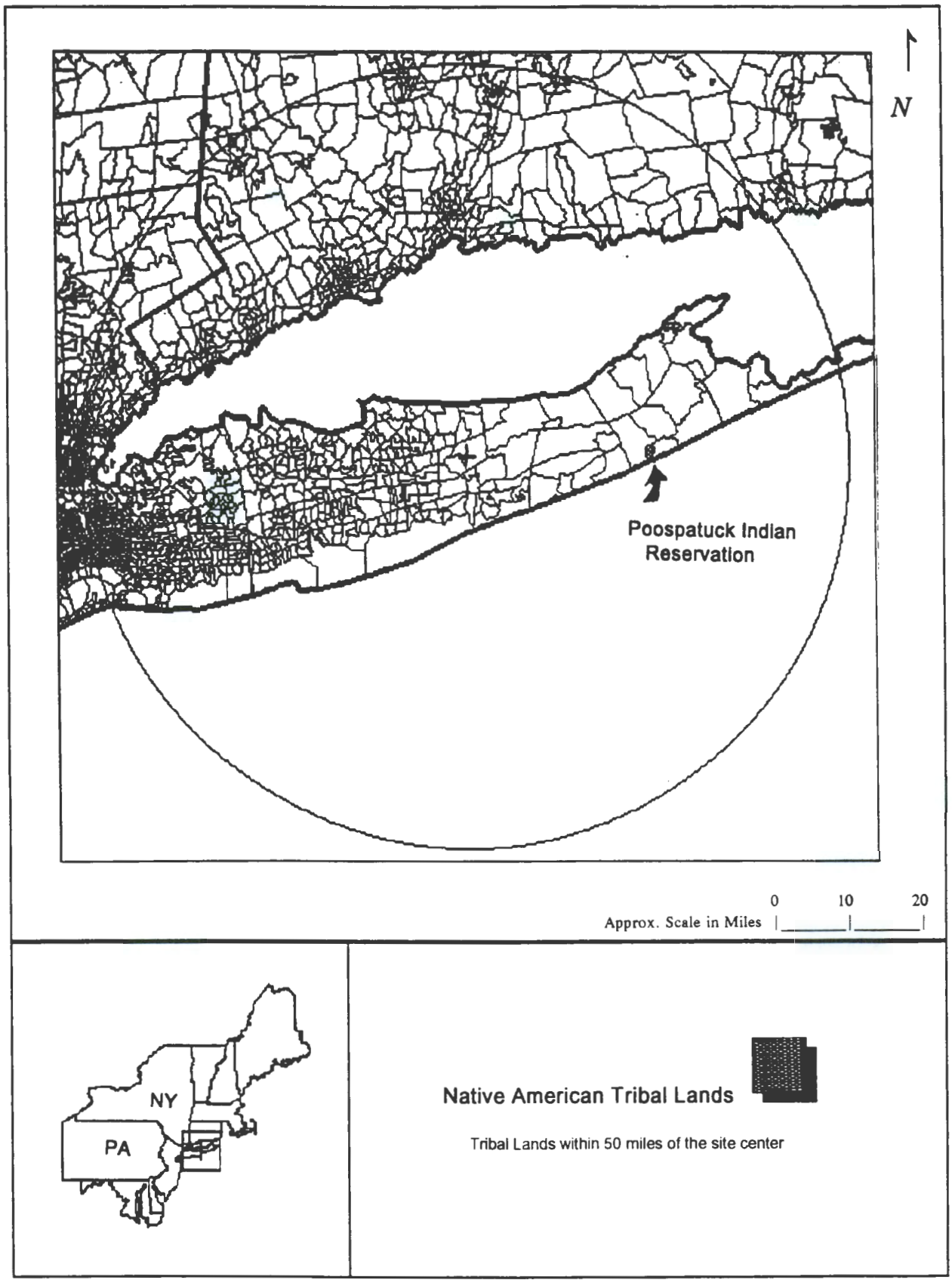

Figure I-2b. Location of Tribal Lands at Brookhaven National Laboratory.

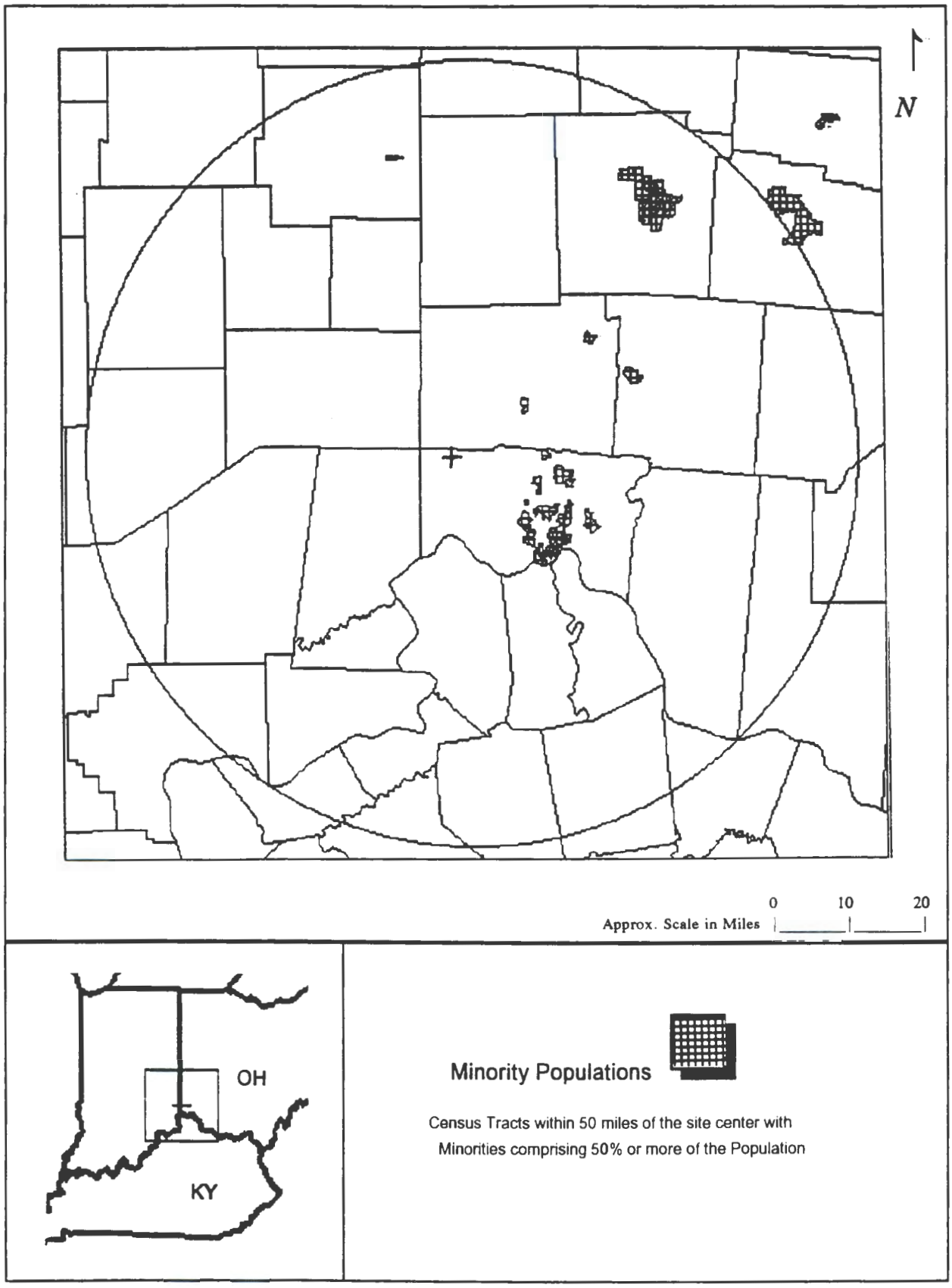

Figure I–3. Distribution of minority populations at Fernald Environmental Management Project.

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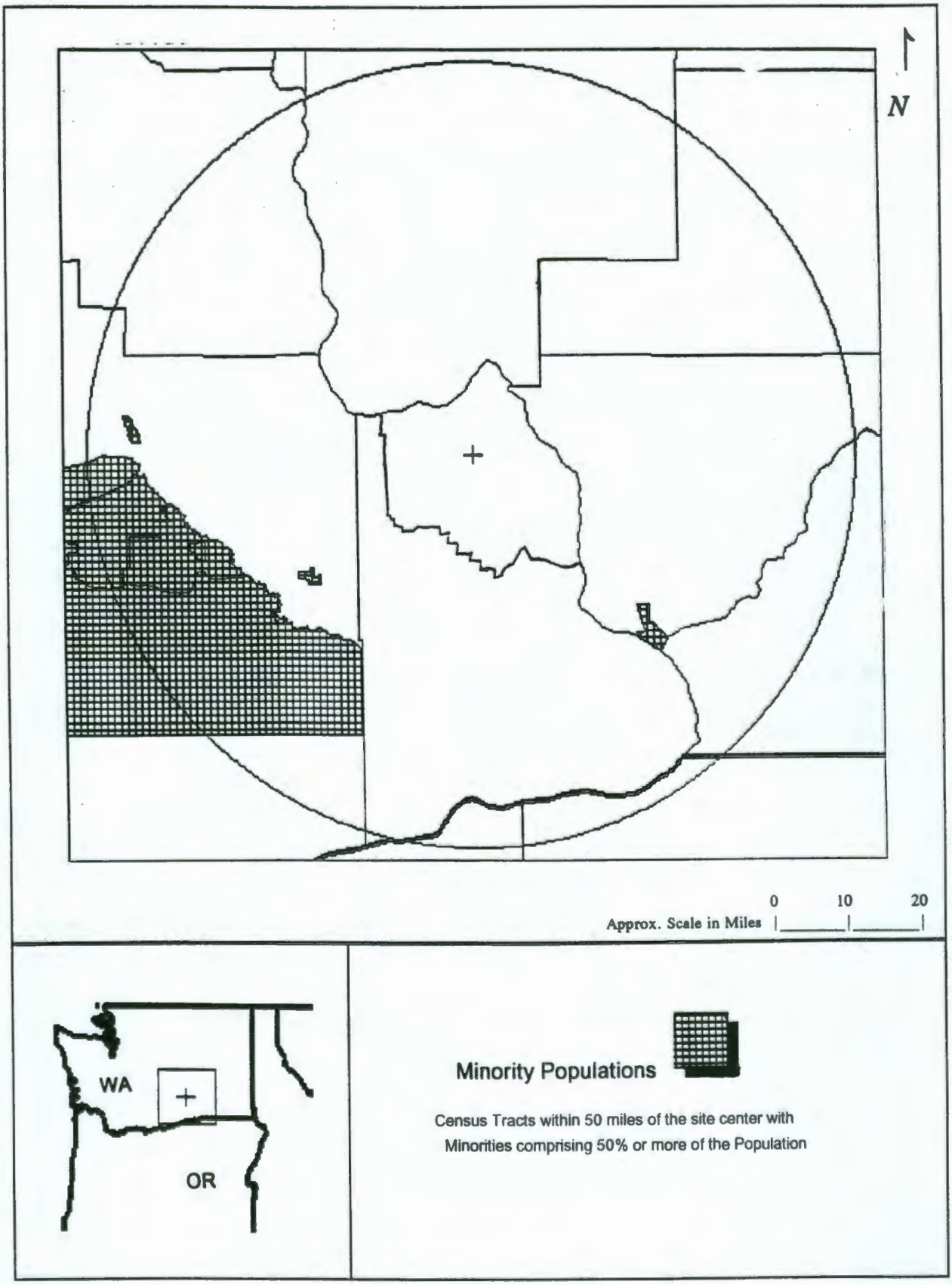

Figure I–4a. Distribution of minority populations at the Hanford Site.

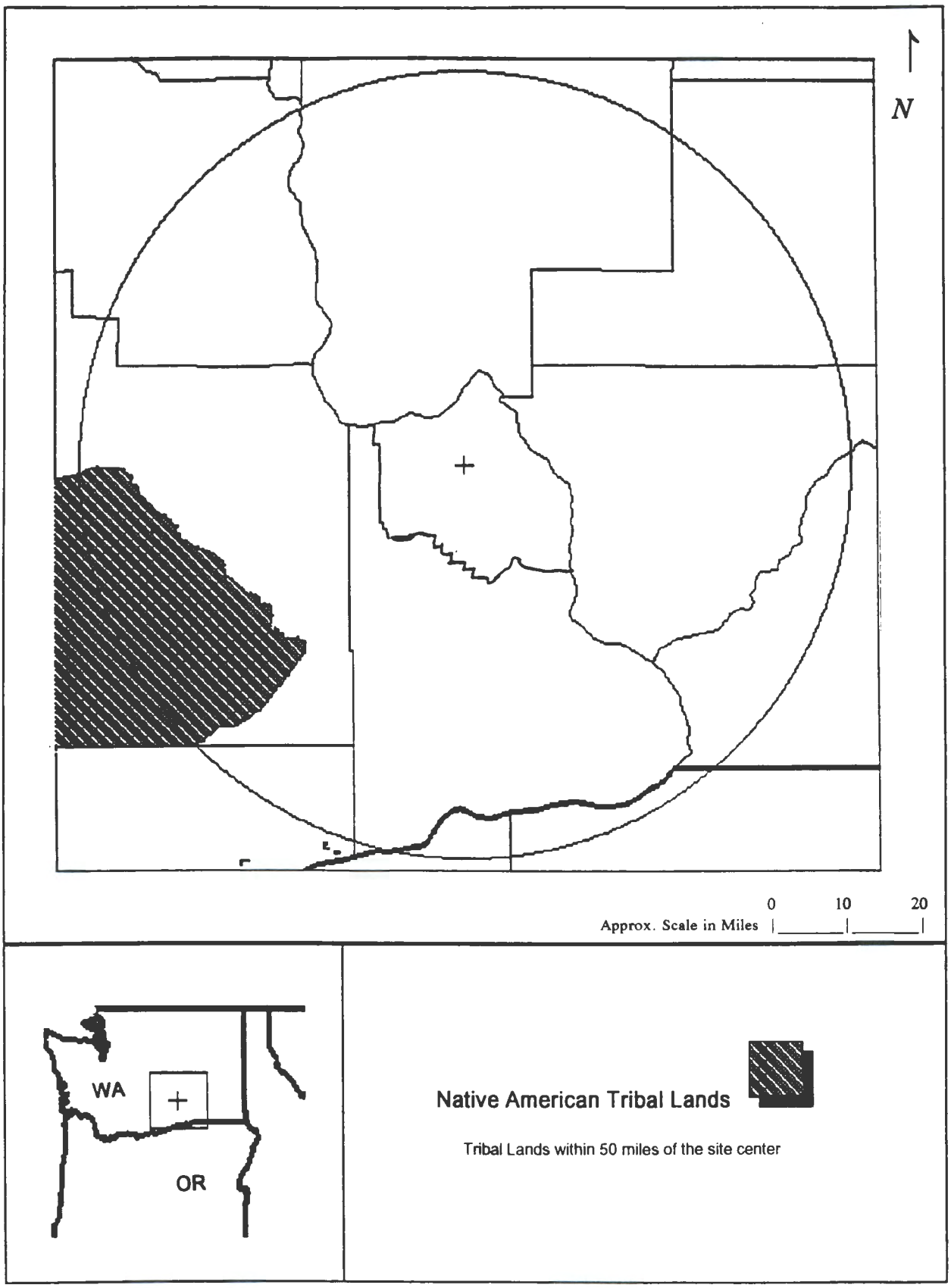

Figure I–4b. Location of Tribal Lands at the Hanford Site.

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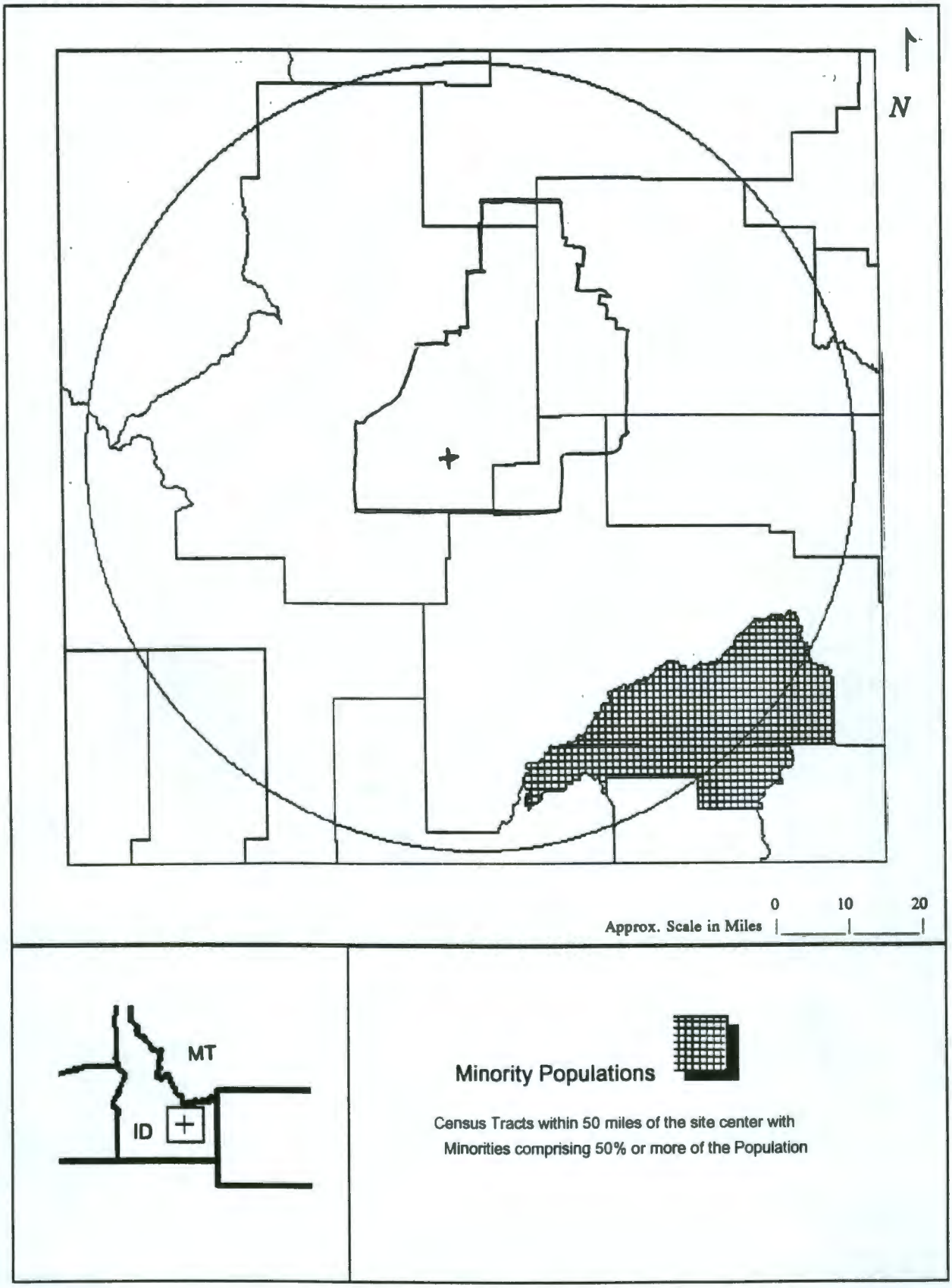

Figure I-5a. Distribution of minority populations at the Idaho National Engineering Laboratory.

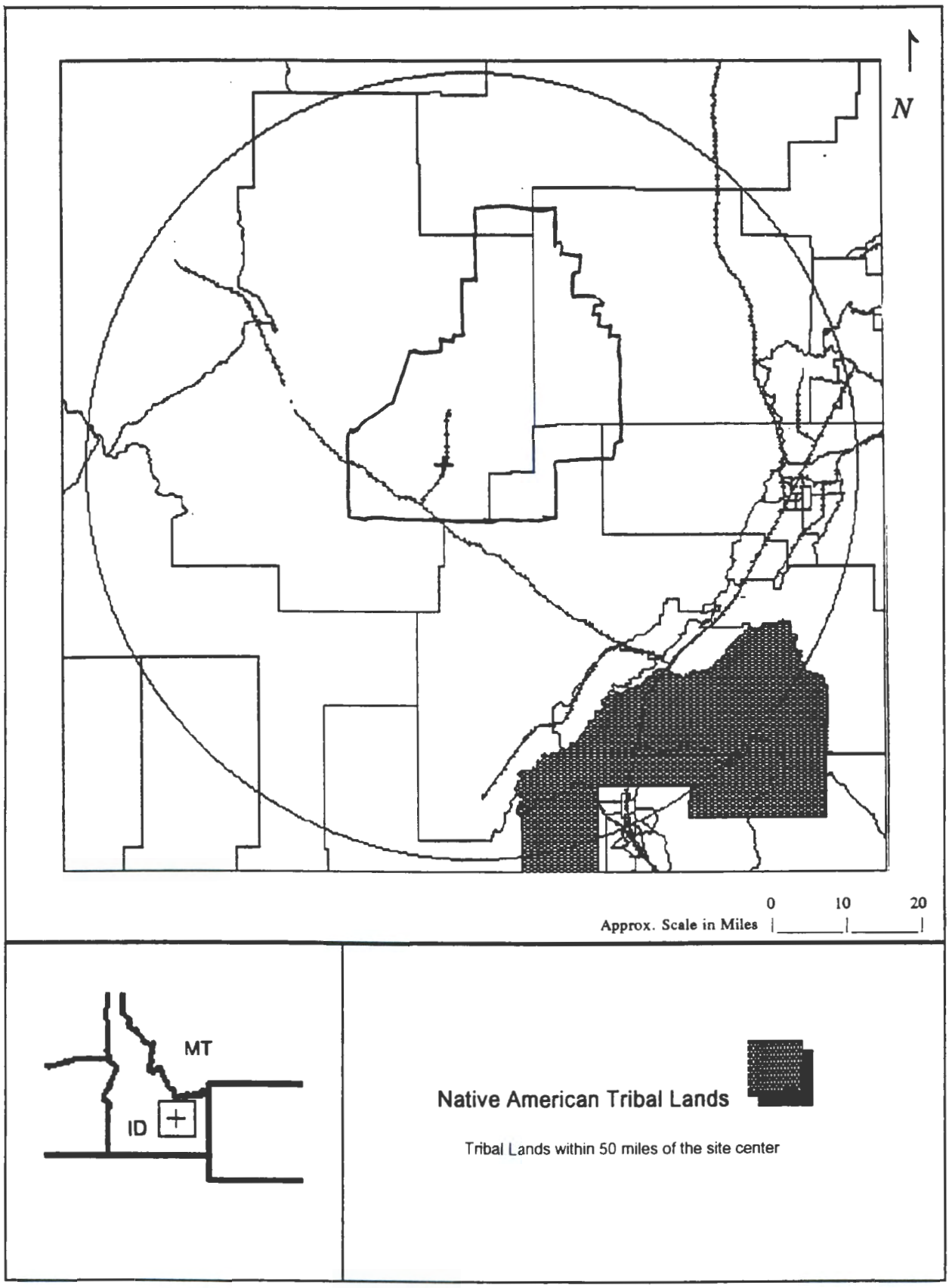

Figure I-5b. Location of Tribal Lands at the Idaho National Engineering Laboratory.

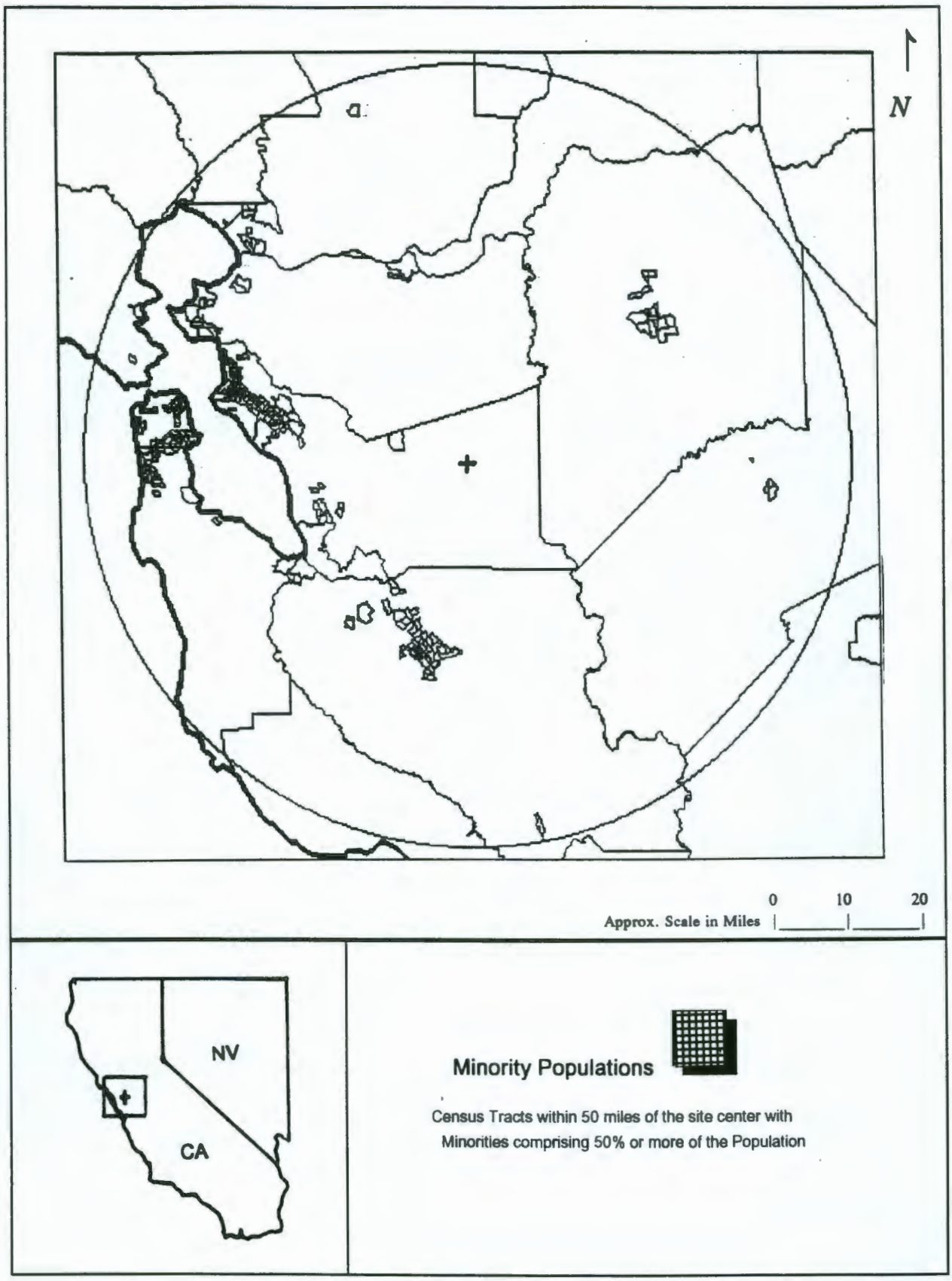

Figure I–6. Distribution of minority populations at Lawrence Livermore National Laboratory.

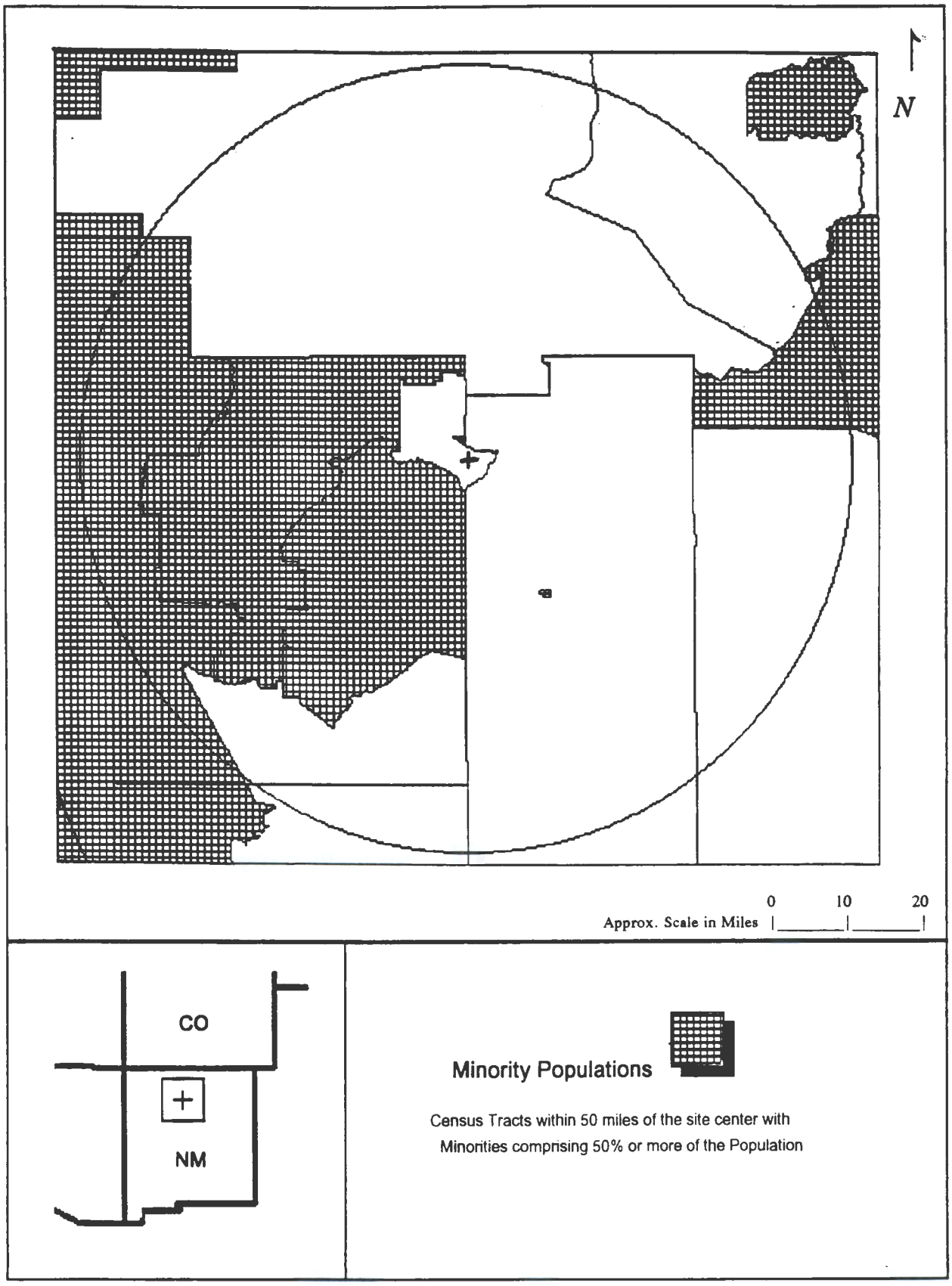

Figure I-7a. Distribution of minority populations at Los Alamos National Laboratory.

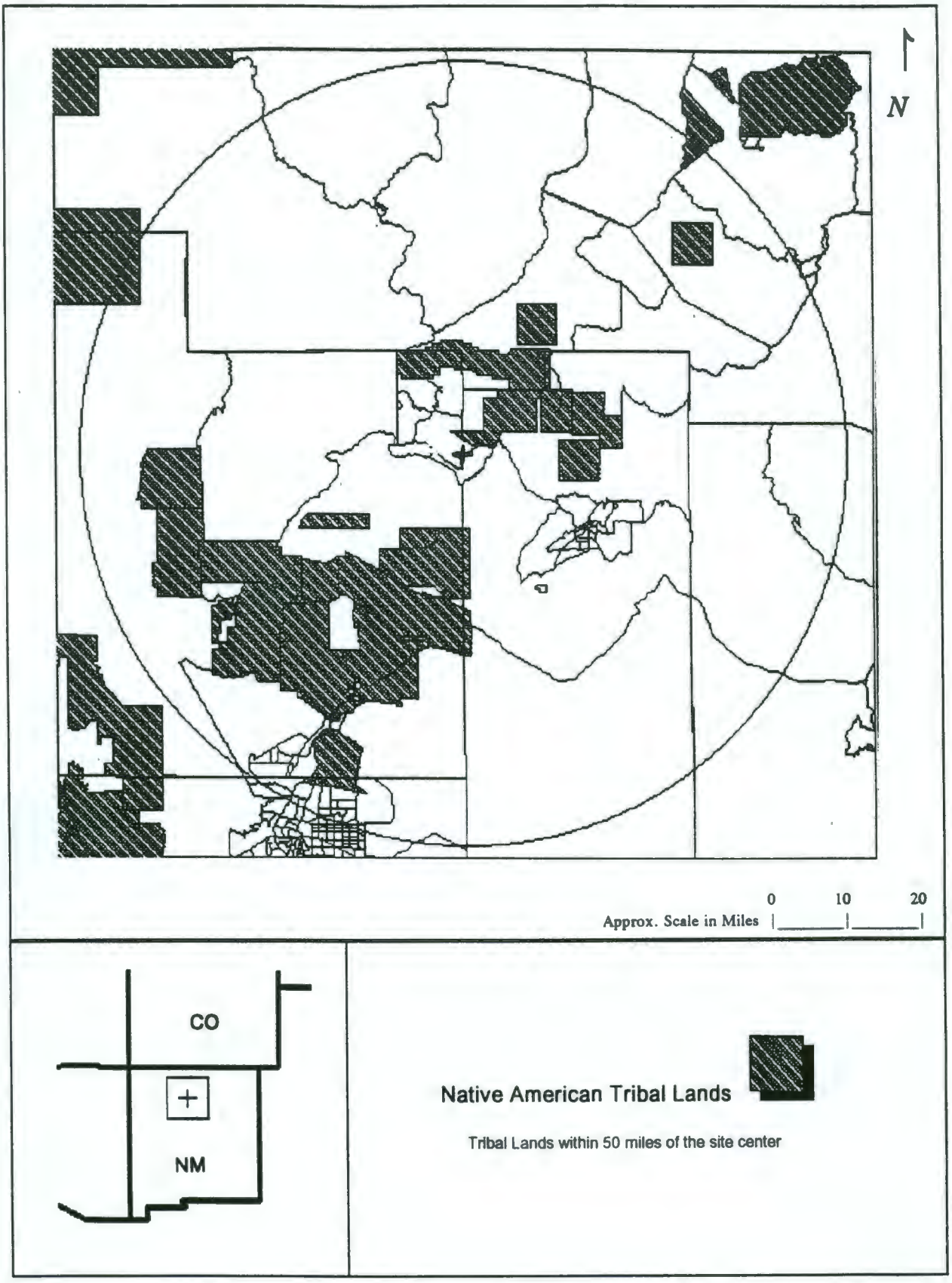

Figure I-7b. Location of Tribal Lands at Los Alamos National Laboratory.

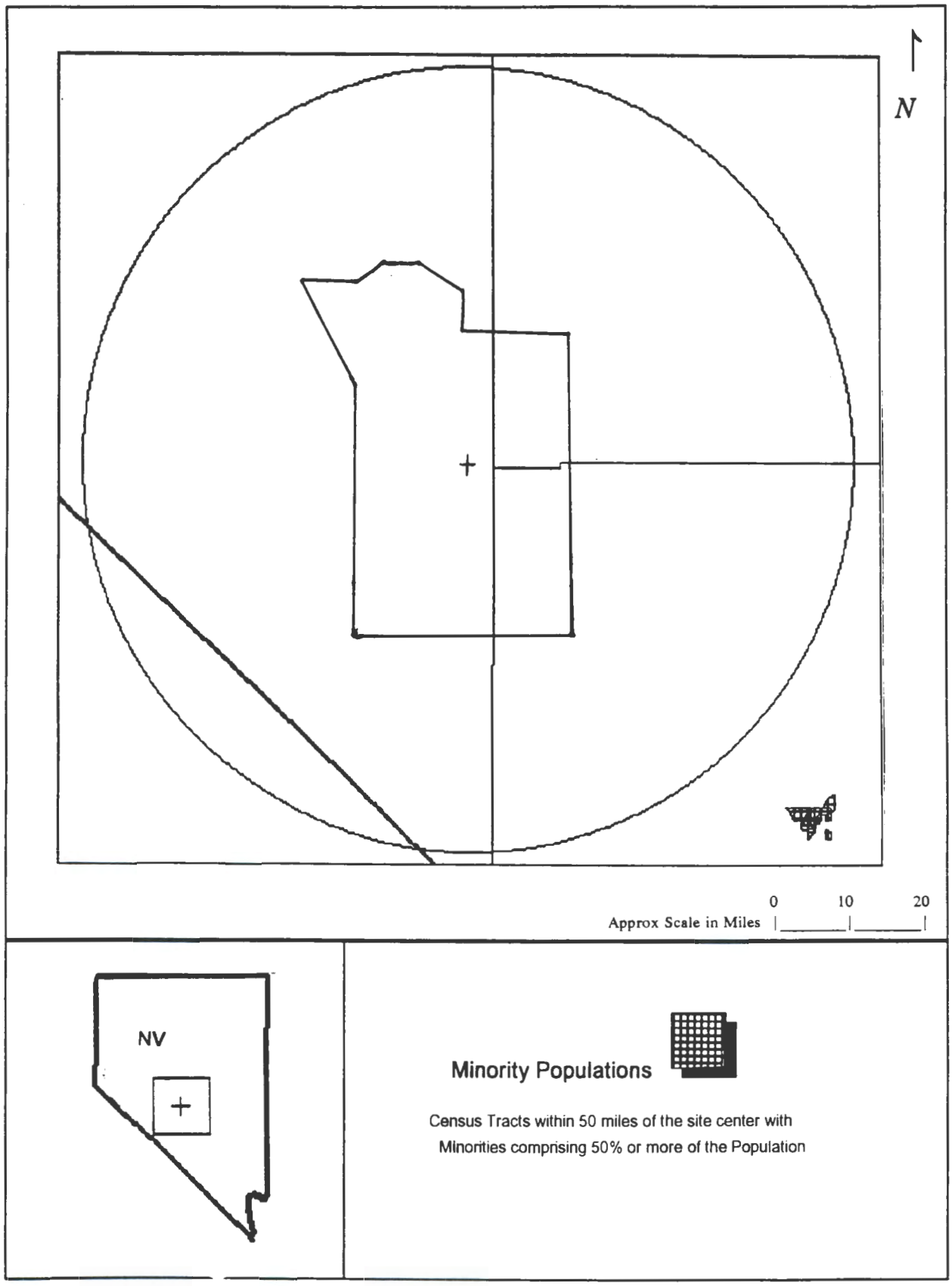

Figure I–8. Distribution of minority populations at the Nevada Test Site.

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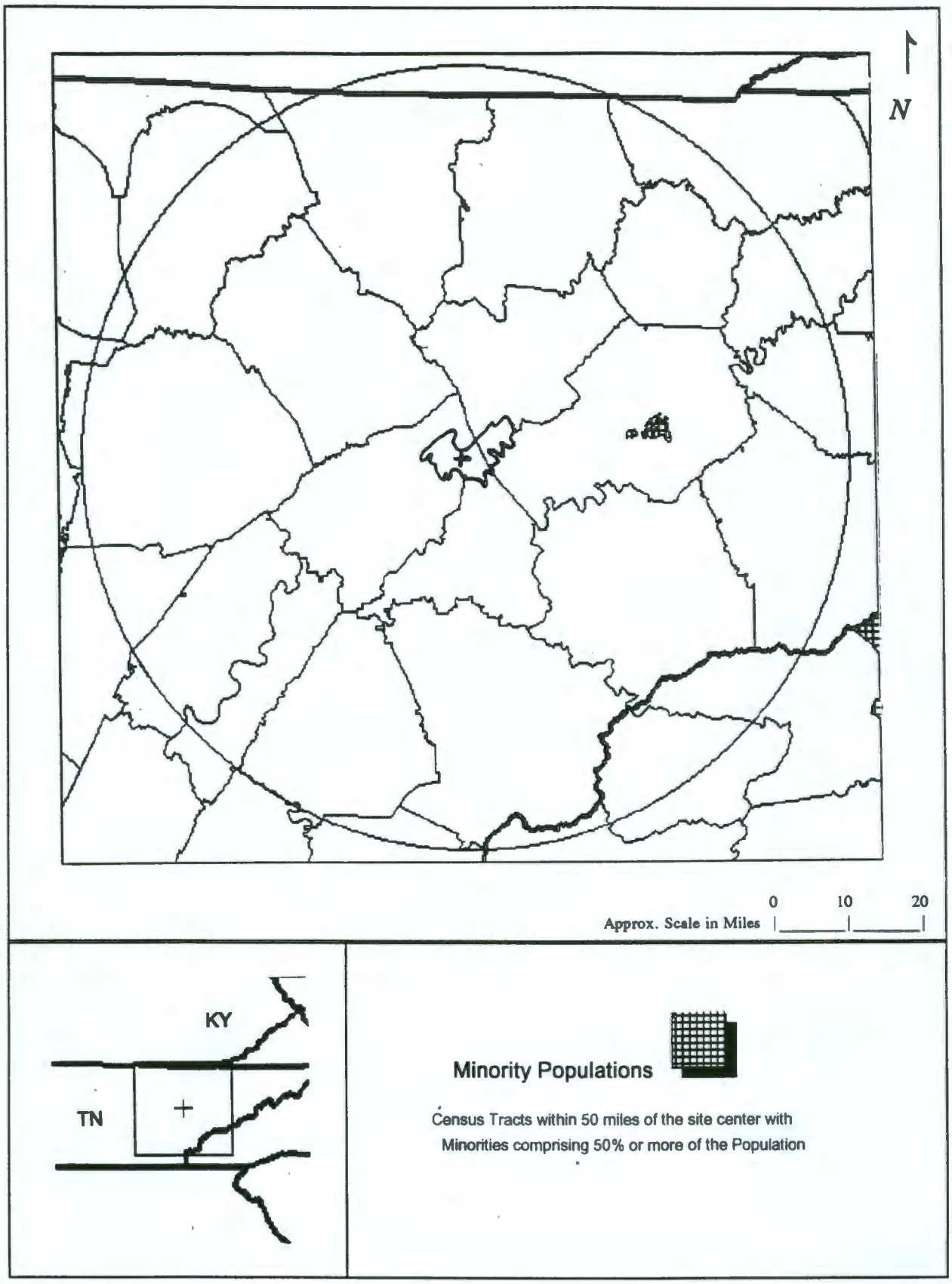

Figure I–9. Distribution of minority populations at the Oak Ridge Reservation.

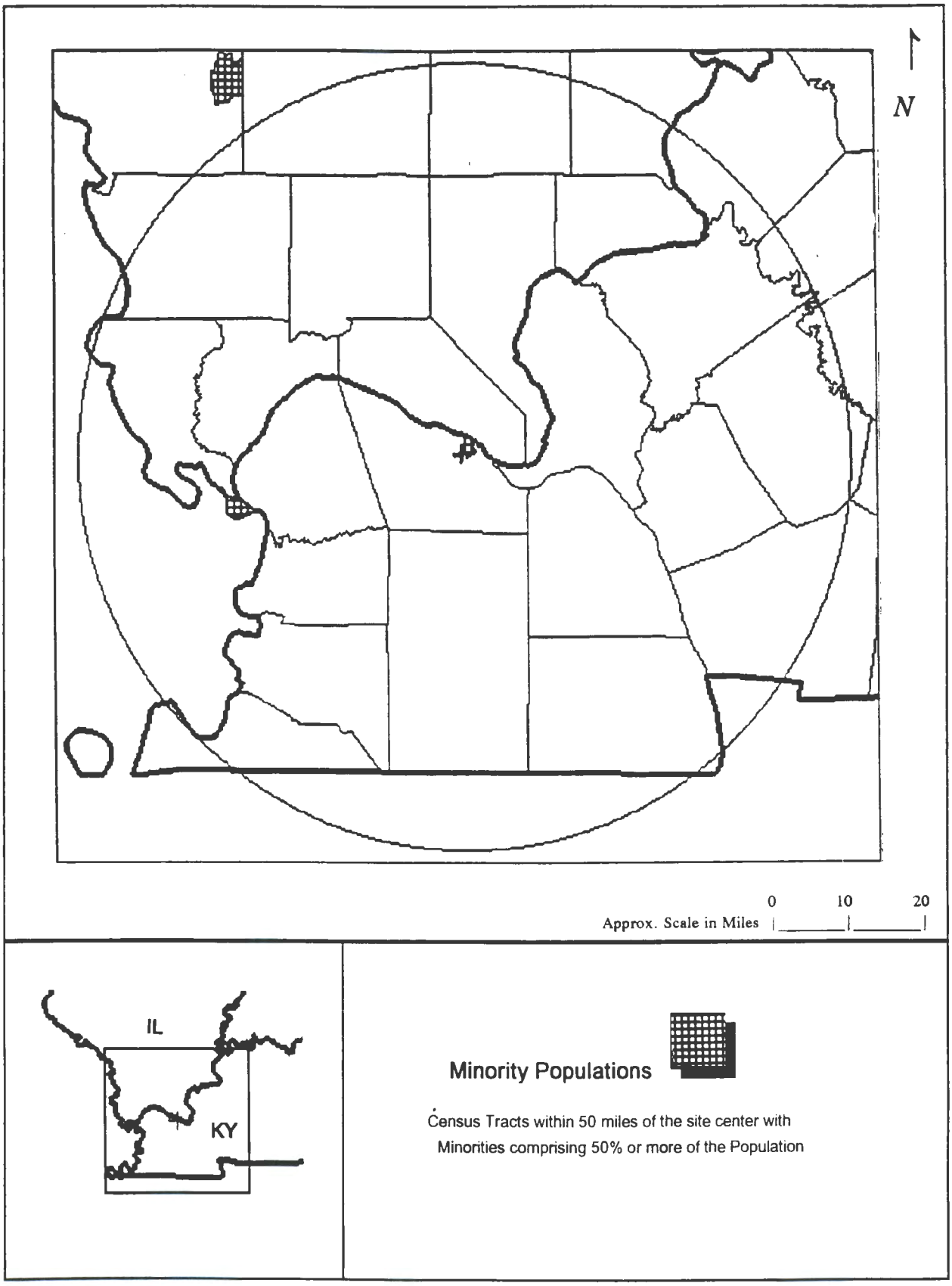

Figure I–10. Distribution of minority populations at the Paducah Gaseous Diffusion Plant.

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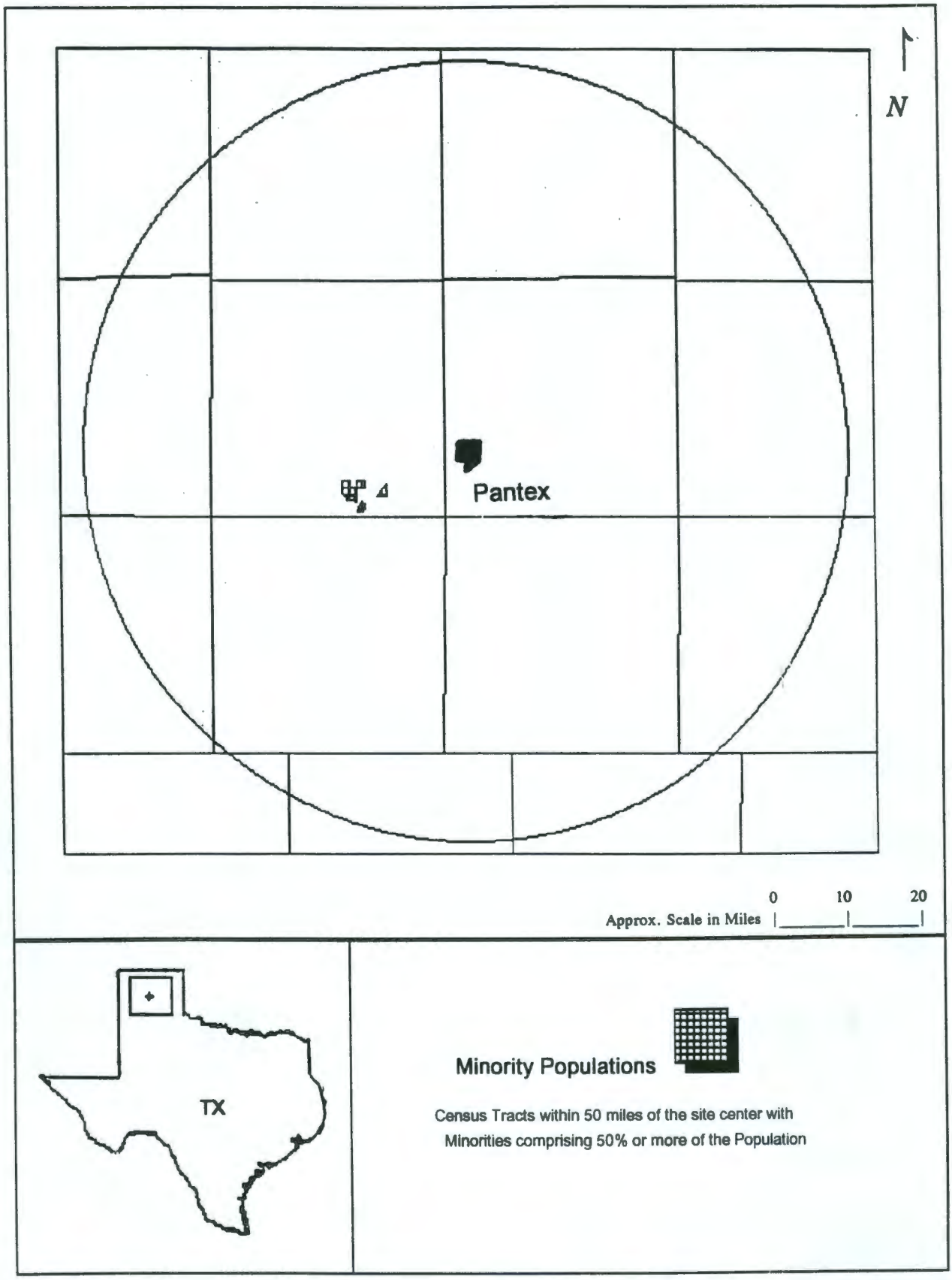

Figure I–11. Distribution of minority populations at the Pantex Plant.

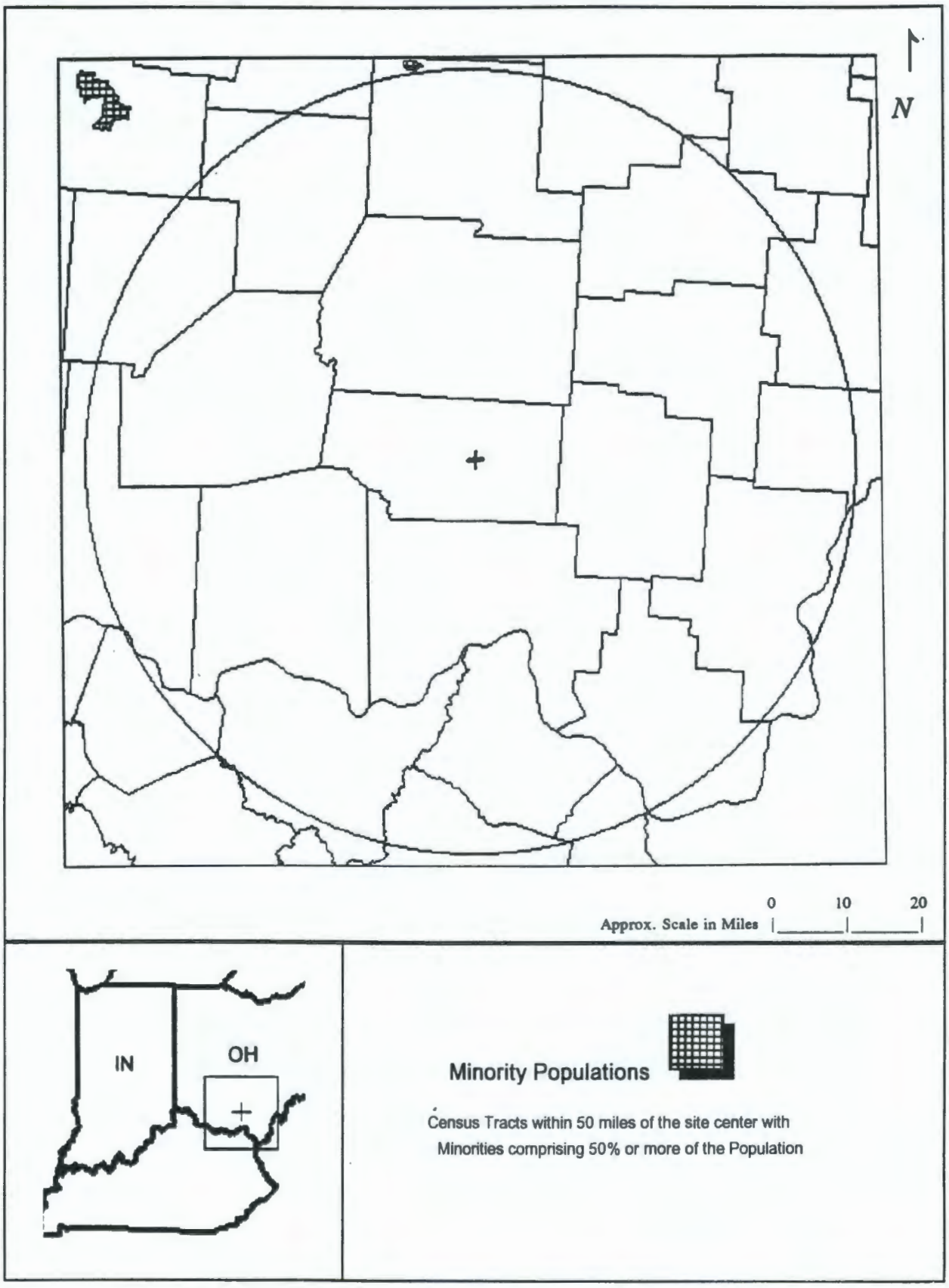

Figure I–12. Distribution of minority populations at the Portsmouth Gaseous Diffusion Plant.

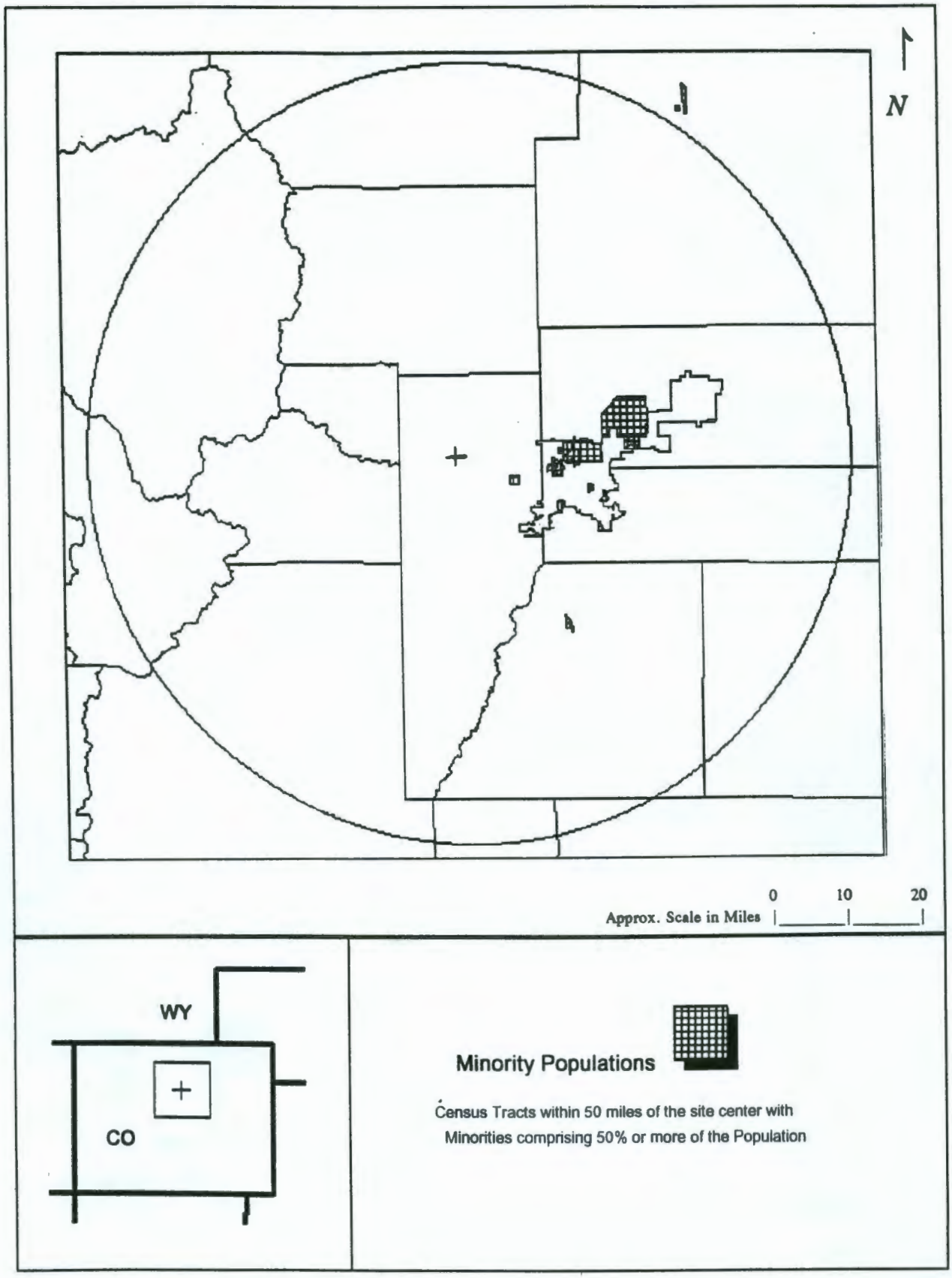

Figure I–13. Distribution of minority populations at Rocky Flats Environmental Technology Site.

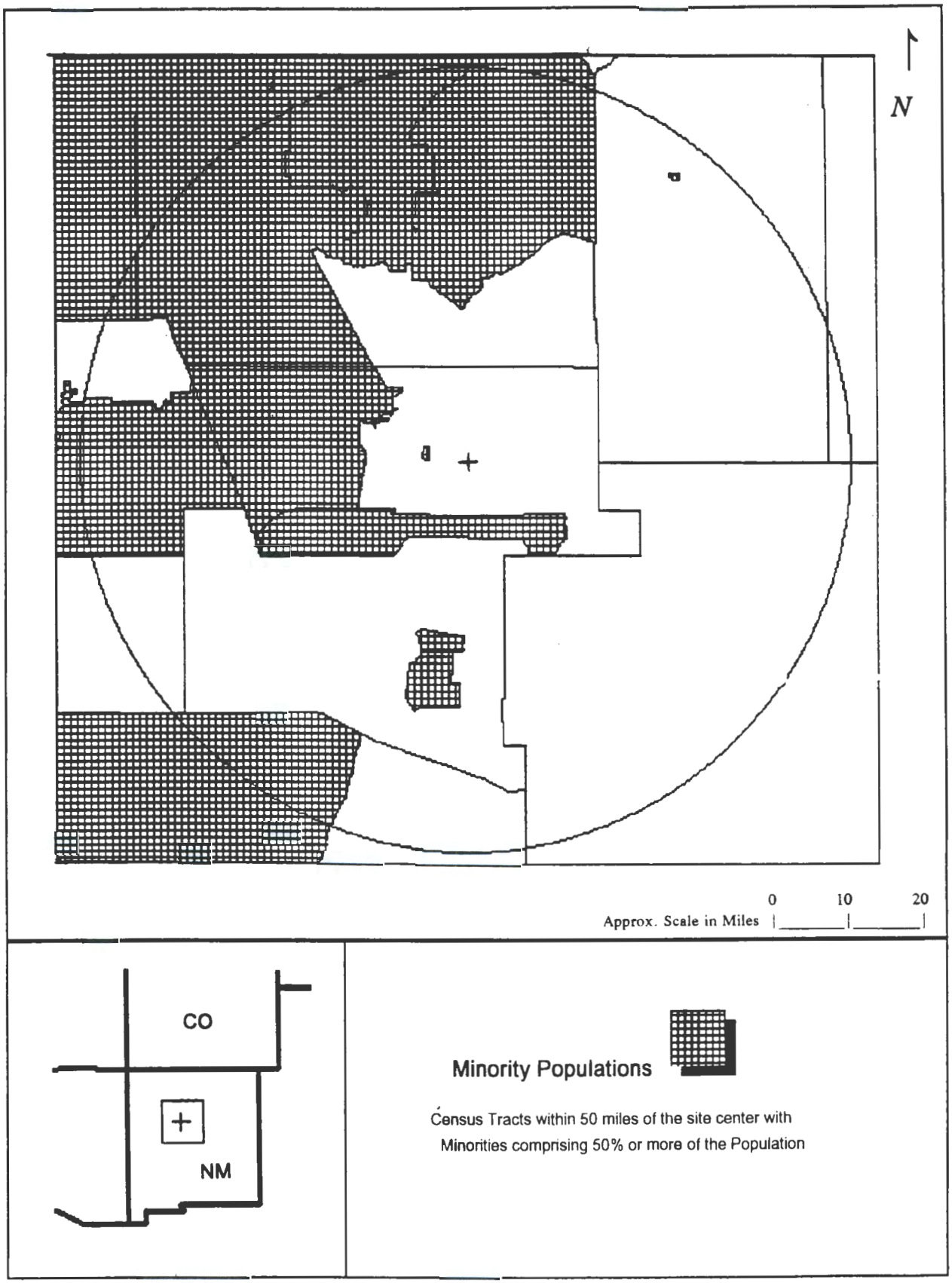

Figure I-14a. Distribution of minority populations at Sandia National Laboratory-New Mexico.

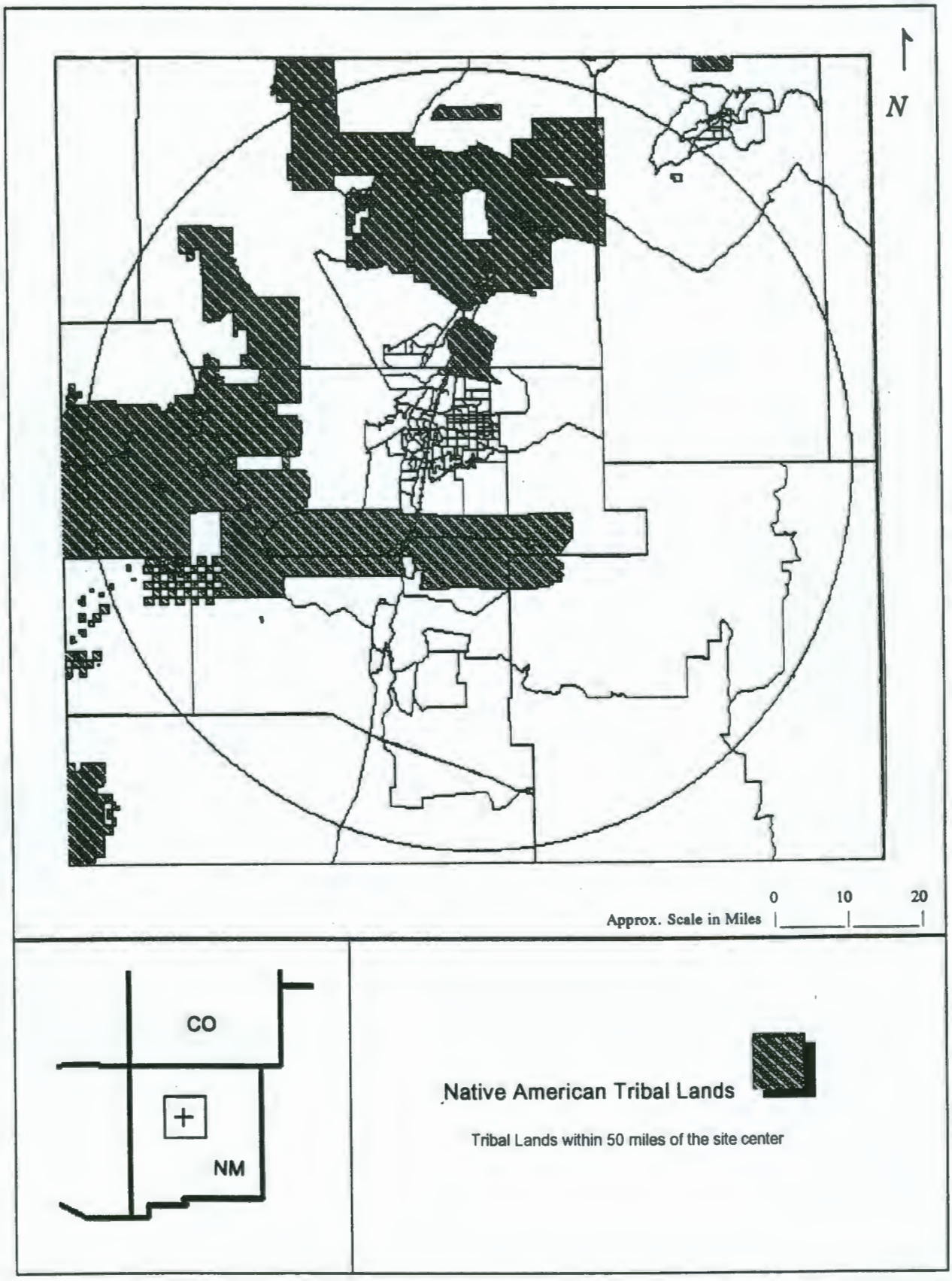

Figure I–14b. Location of Tribal Lands at Sandia National Laboratory-New Mexico.

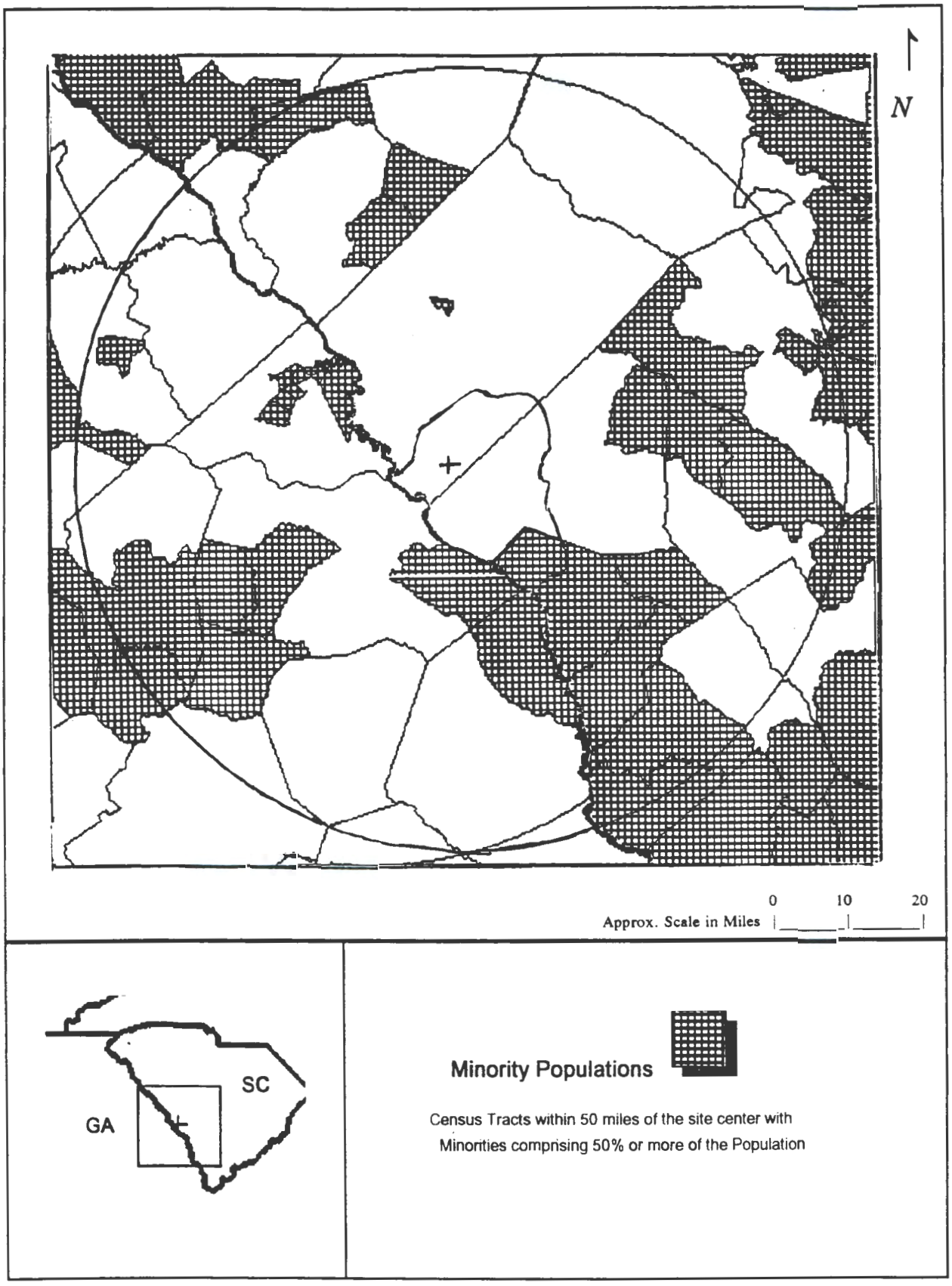

Figure I–15. Distribution of minority populations at the Savannah River Site.

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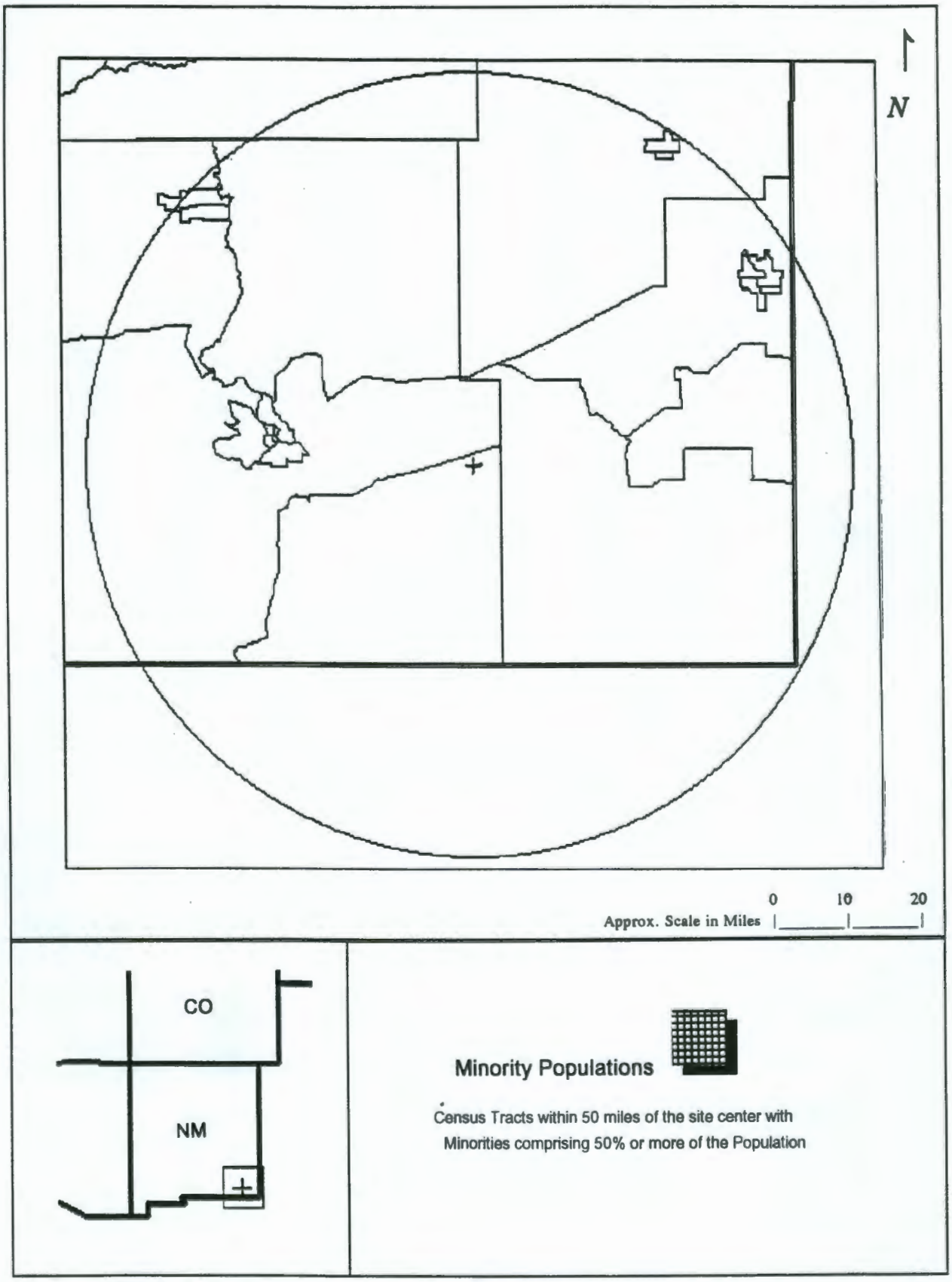

Figure I–16. Distribution of minority populations at the Waste Isolation Pilot Plant.

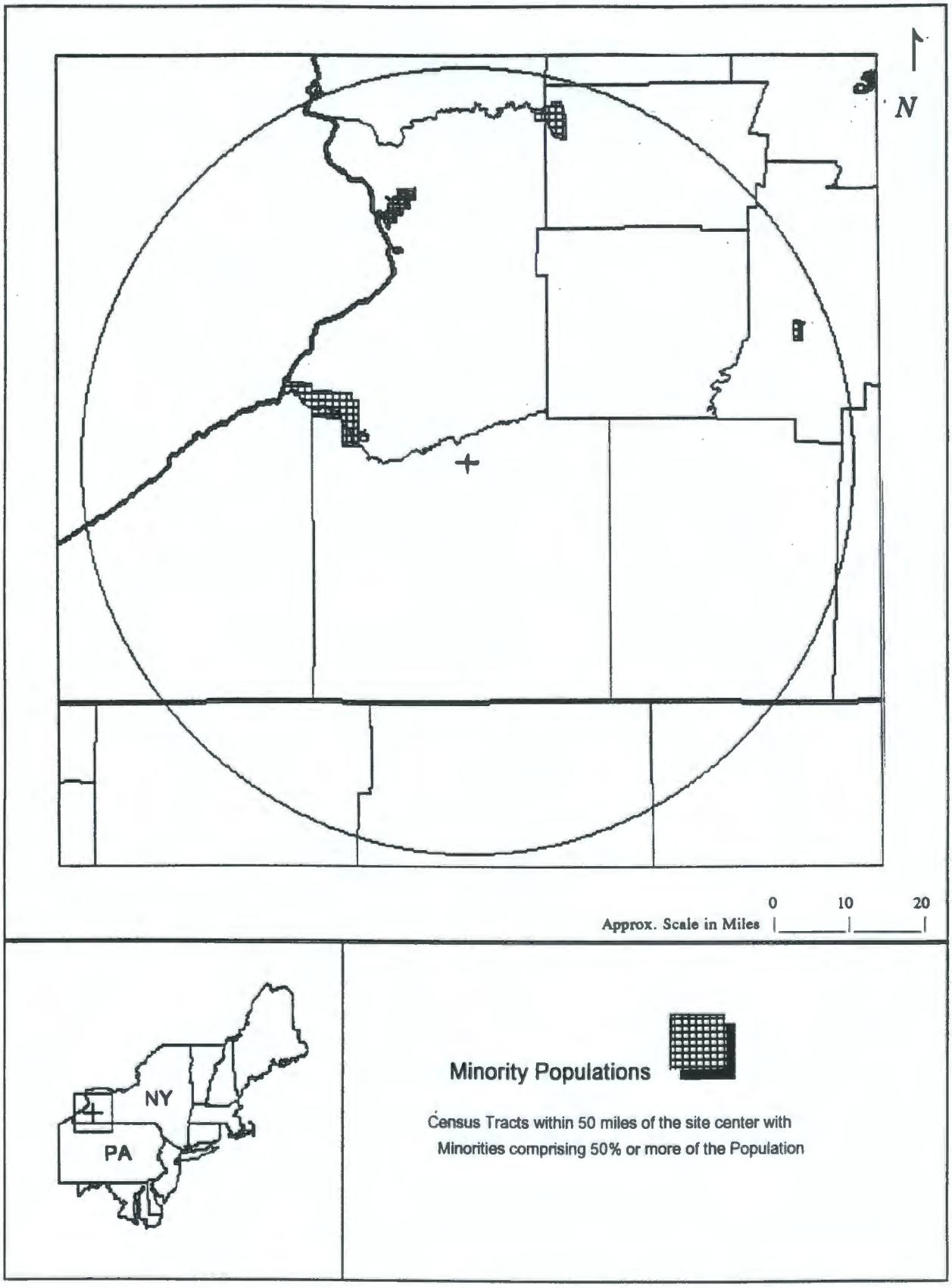

Figure I–17a Distribution of minority populations at the West Valley Demonstration Project.

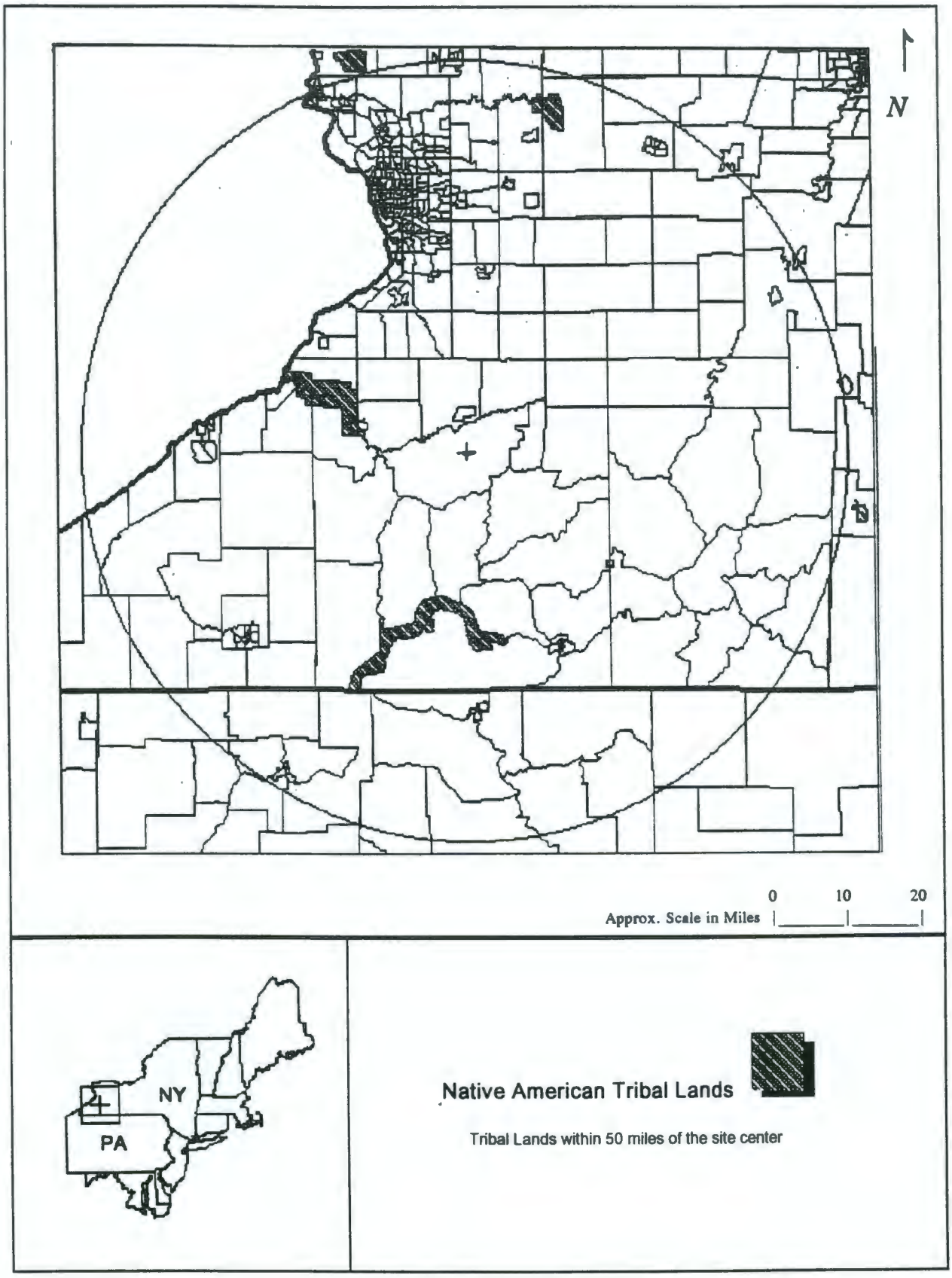

Figure I-17b. Location of Tribal Lands at the West Valley Demonstration Project.

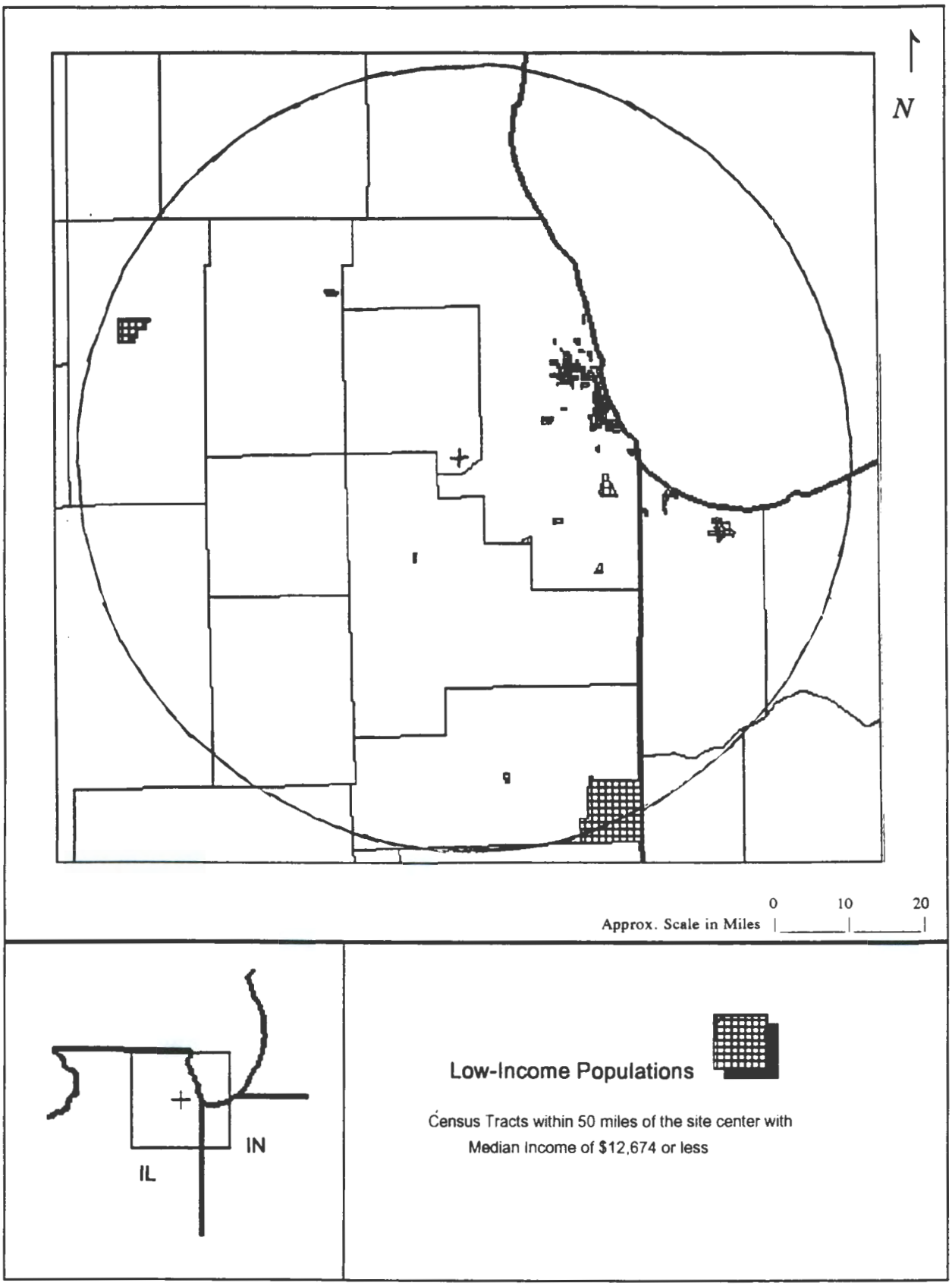

Figure I–18. Distribution of low-income populations at Argonne National Laboratory-East.

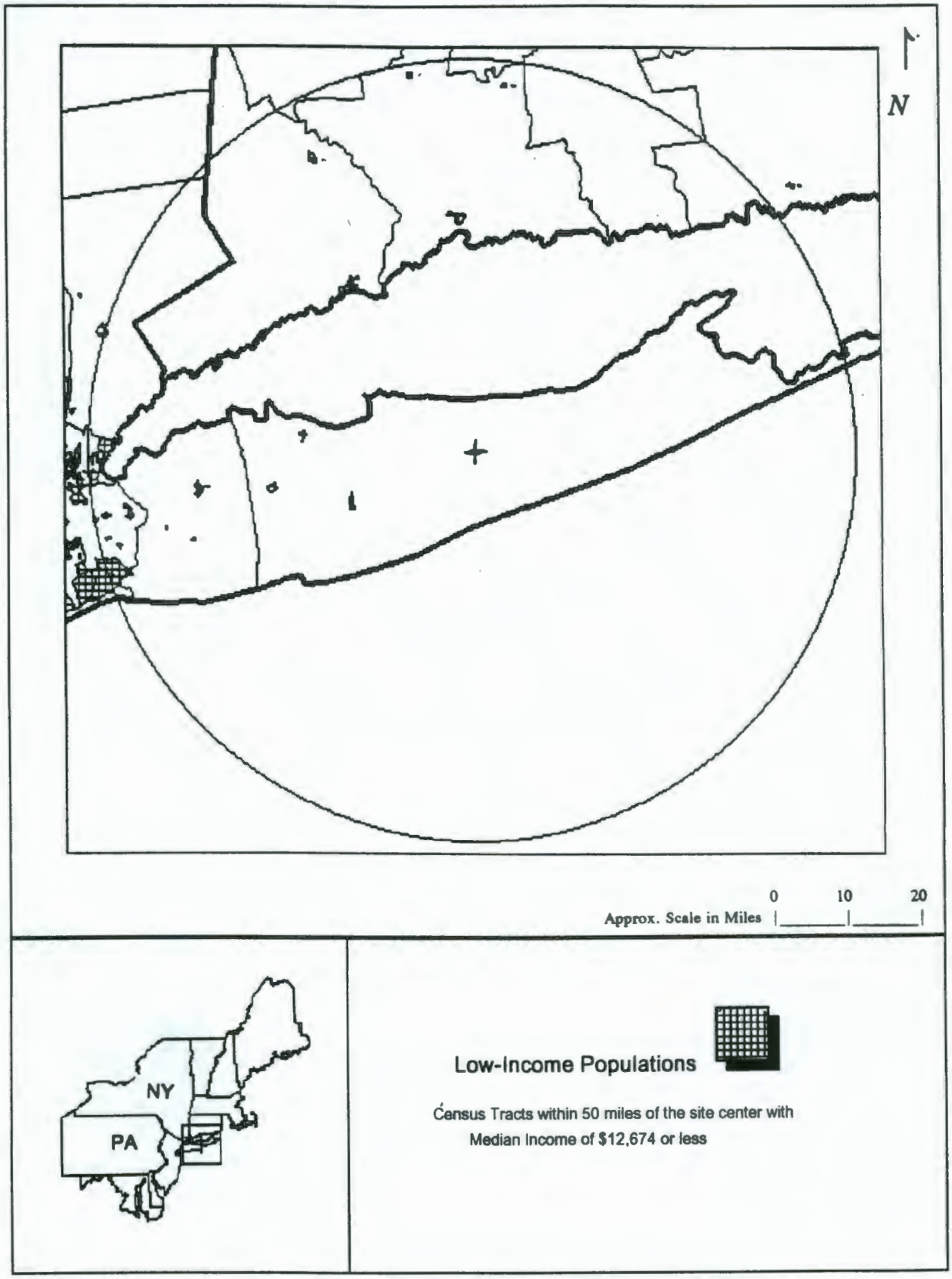

Figure I-19. Distribution of low-income populations at Brookhaven National Laboratory.

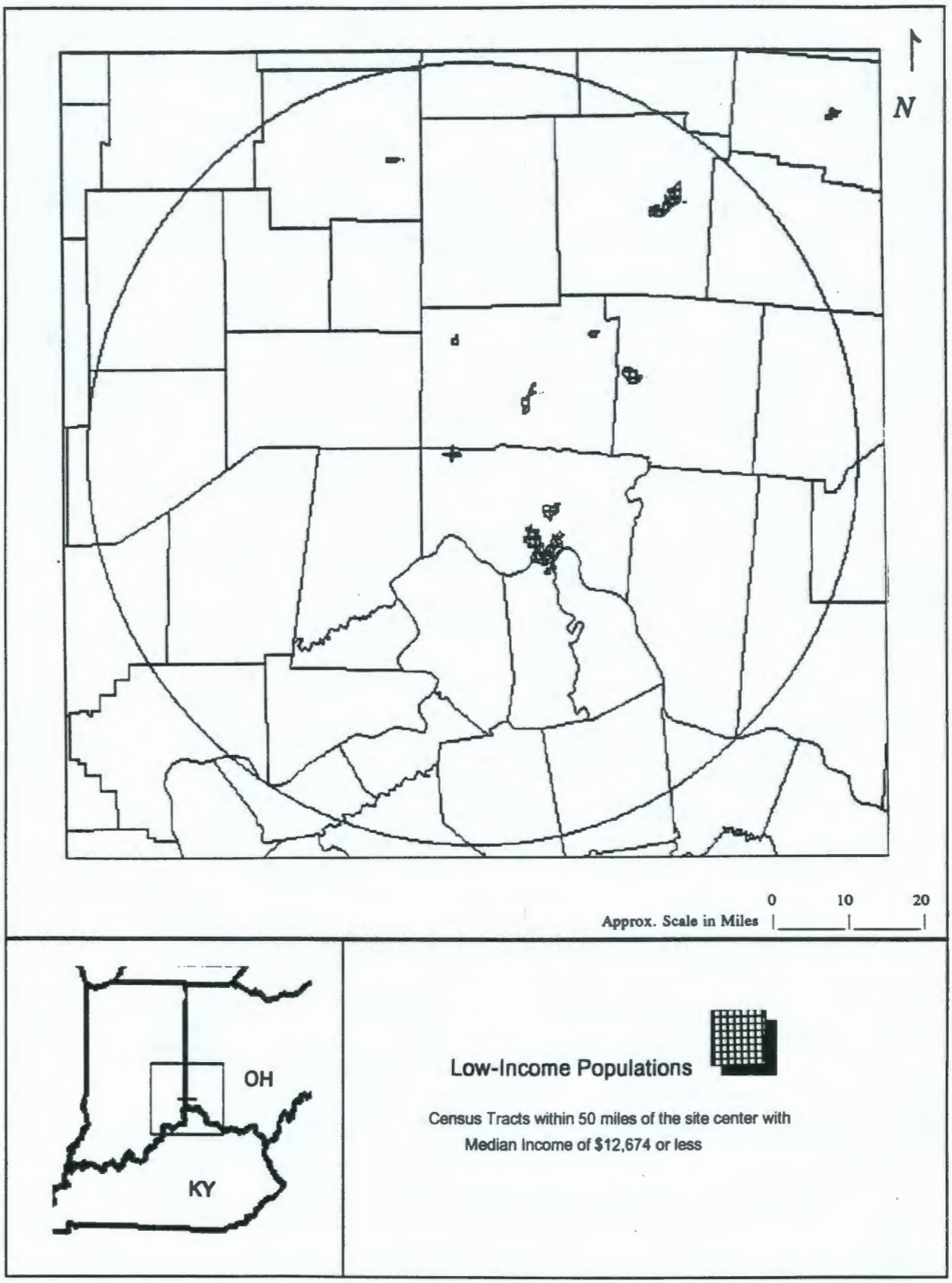

Figure I–20 Distribution of low-income populations at Fernald Environmental Management Project

9513387.2610

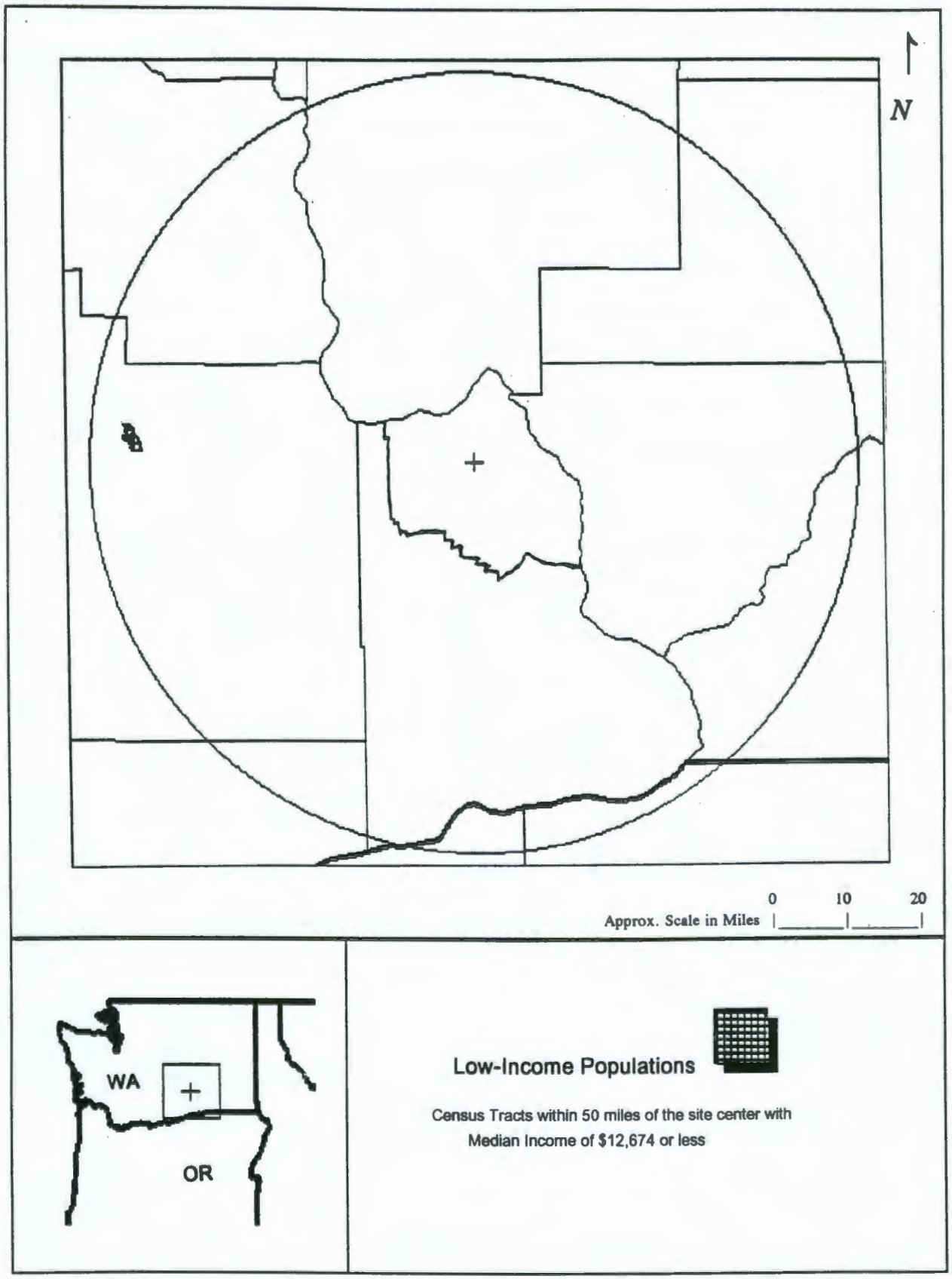

Figure I–21. Distribution of low-income populations at the Hanford Site.

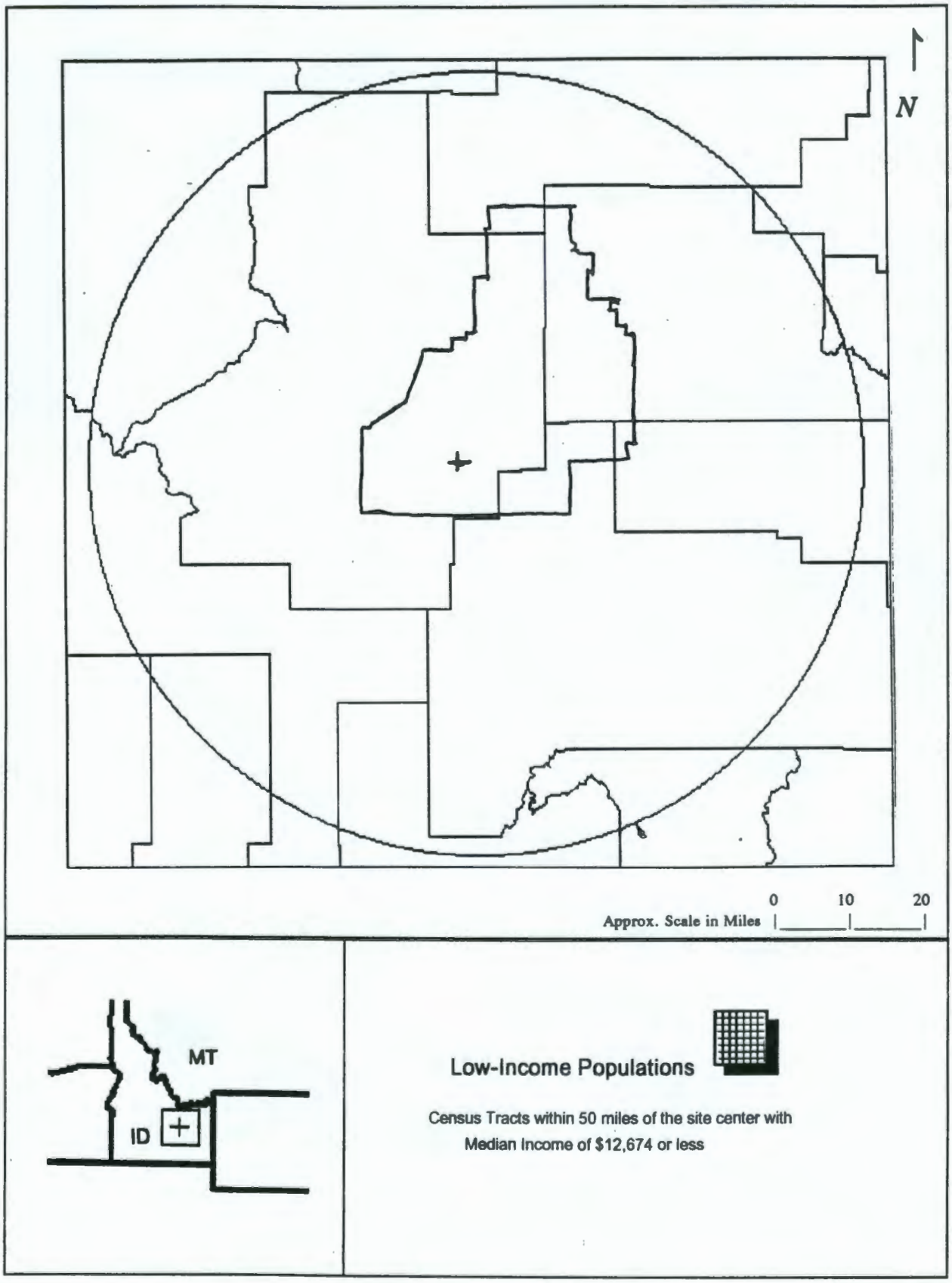

Figure I–22. Distribution of low-income populations at Idaho National Engineering Laboratory.

9513387.2611

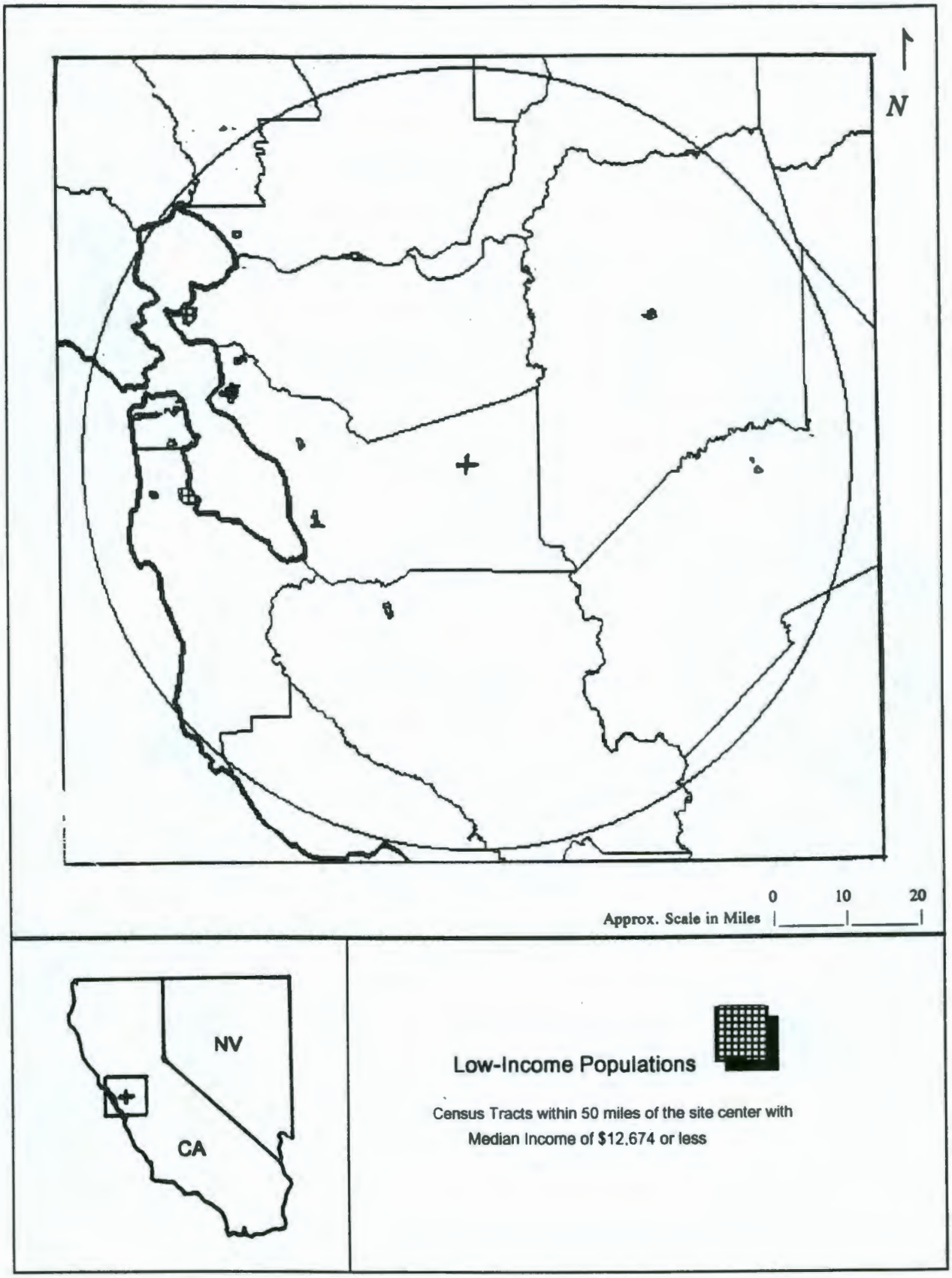

Figure I–23. Distribution of low-income populations at Lawrence Livermore National Laboratory.

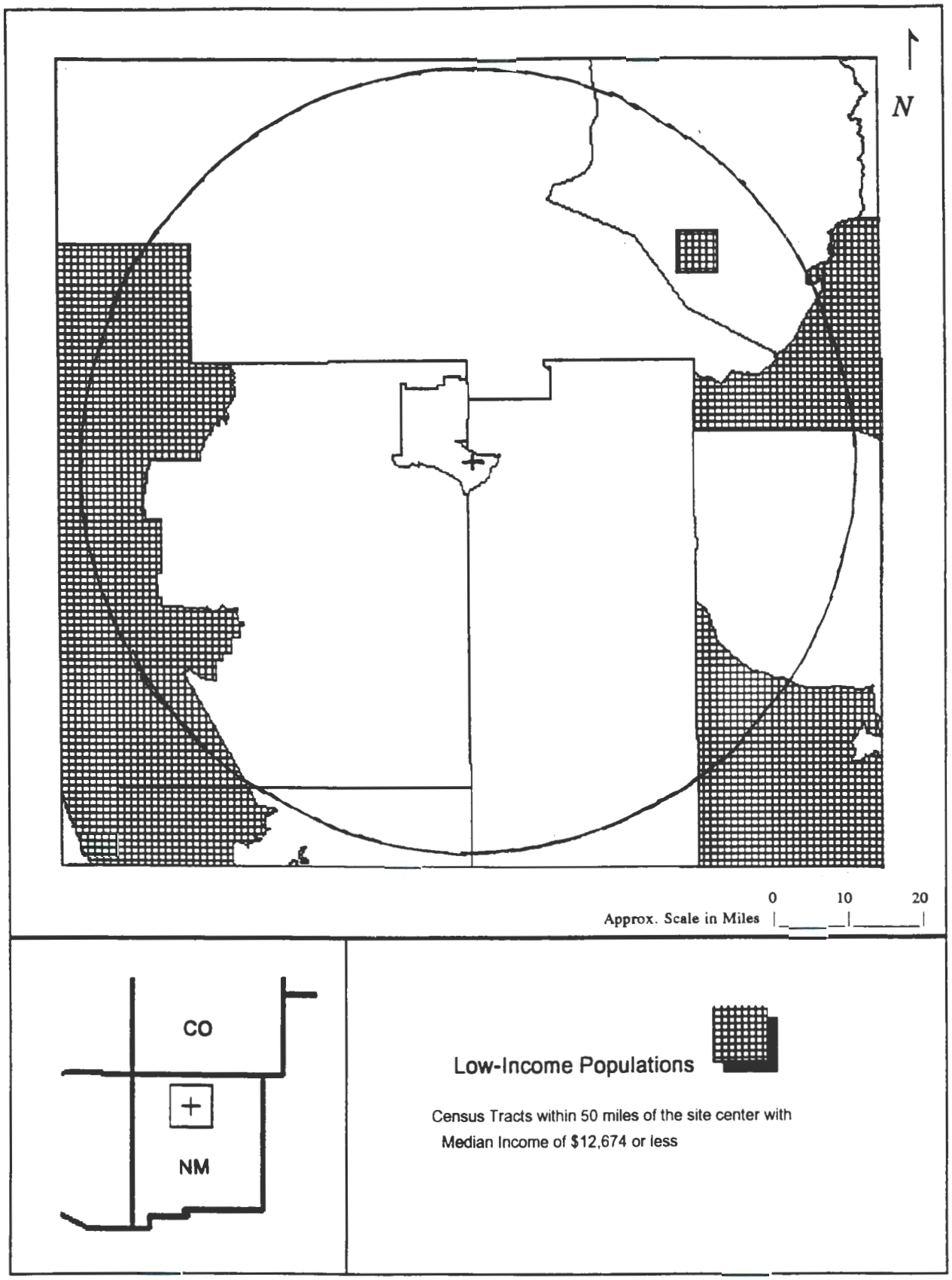

Figure I-24. Distribution of low-income populations at Los Alamos National Laboratory.

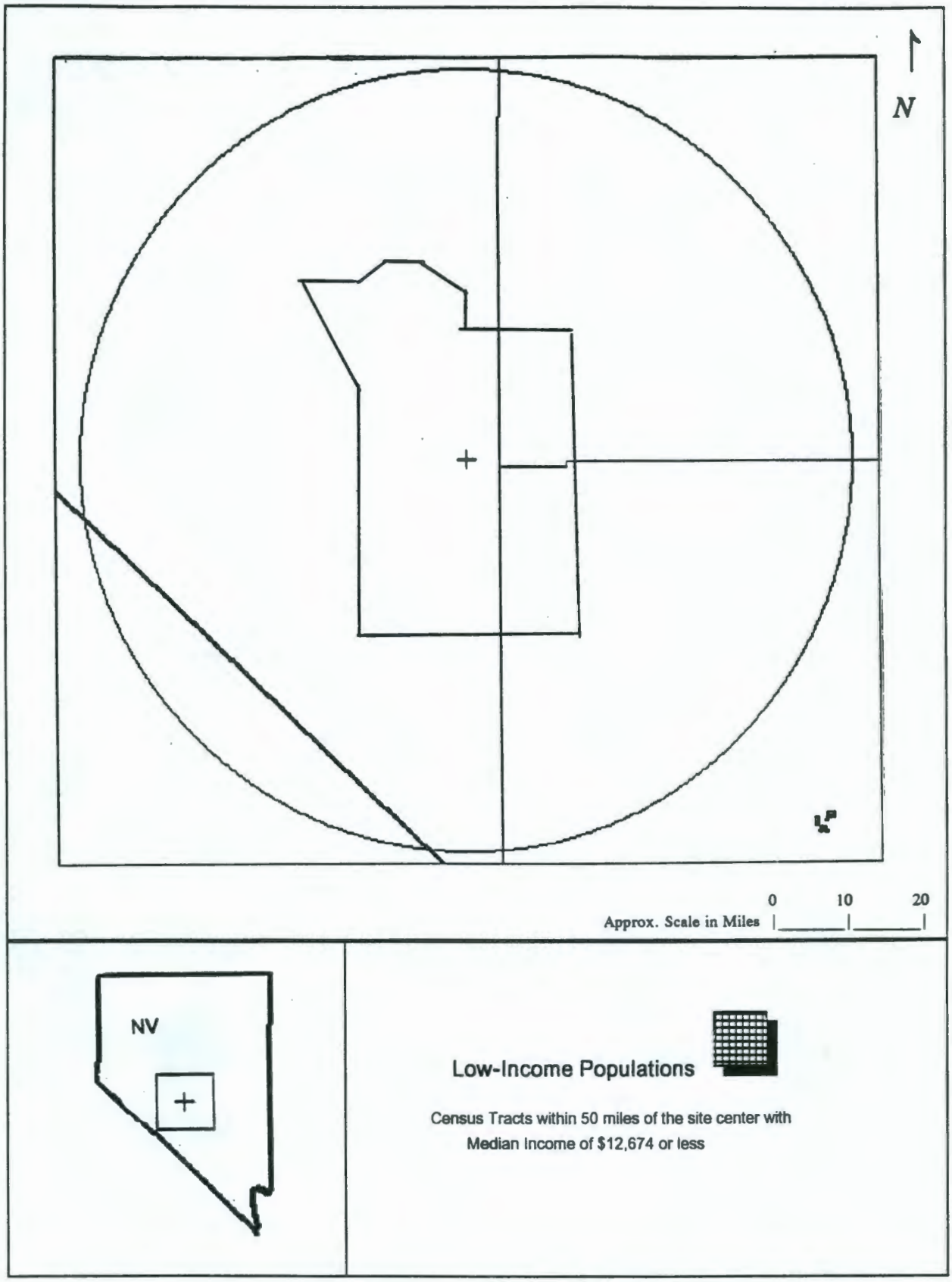

Figure I–25. Distribution of low-income populations at the Nevada Test Site.

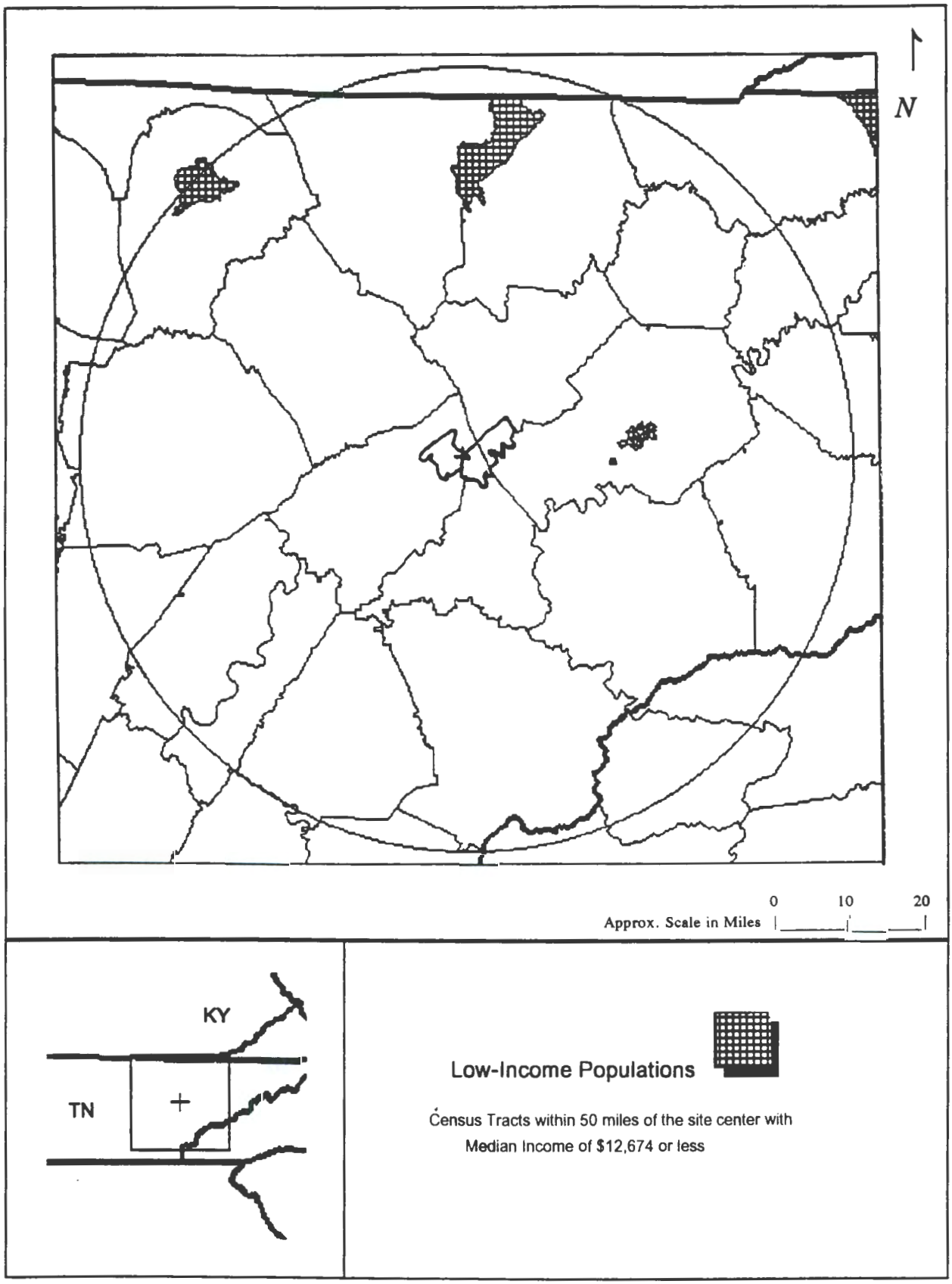

Figure I–26. Distribution of low-income populations at the Oak Ridge Reservation.

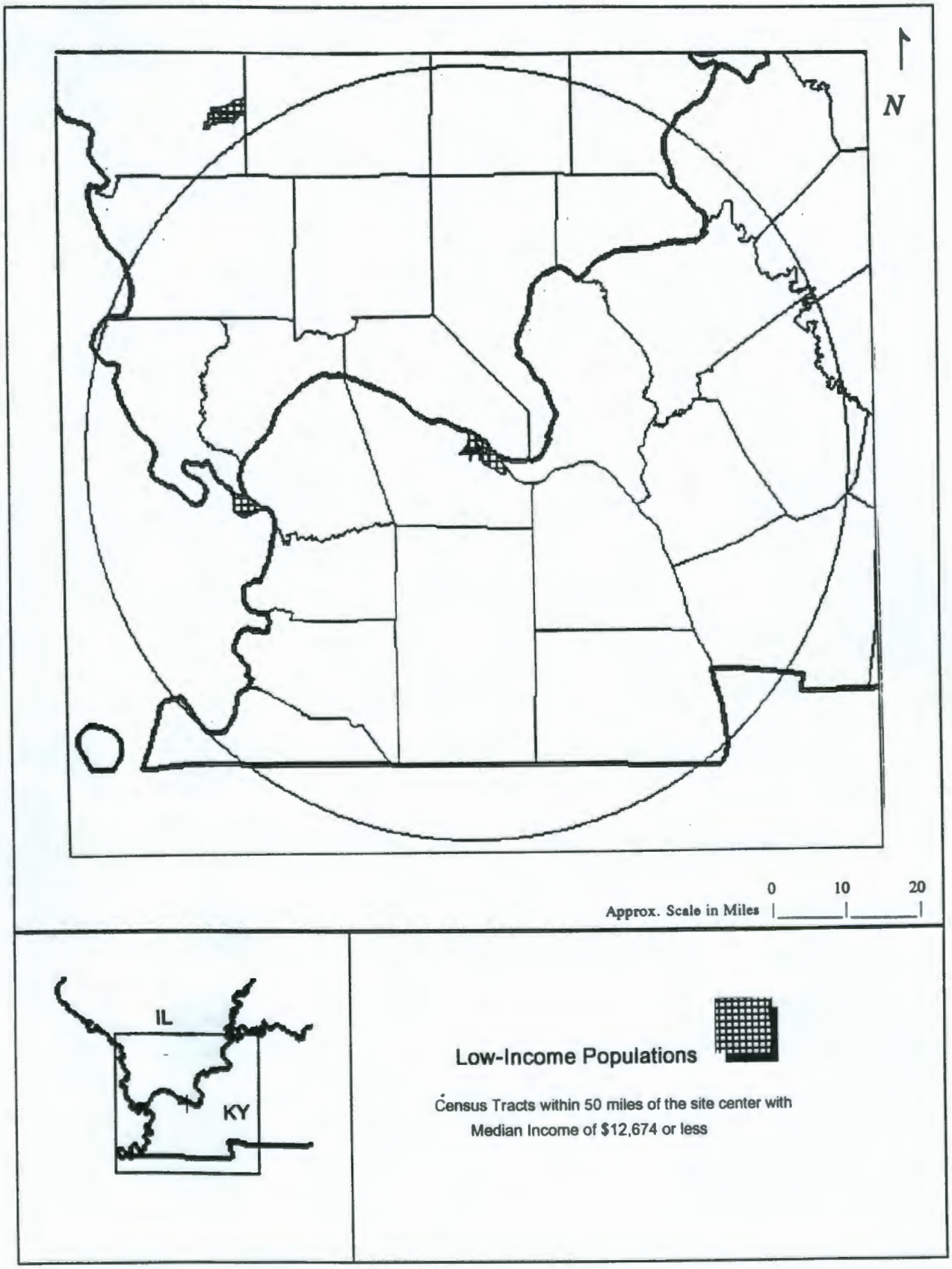

Figure I–27. Distribution of low-income populations at the Paducah Gaseous Diffusion Plant.

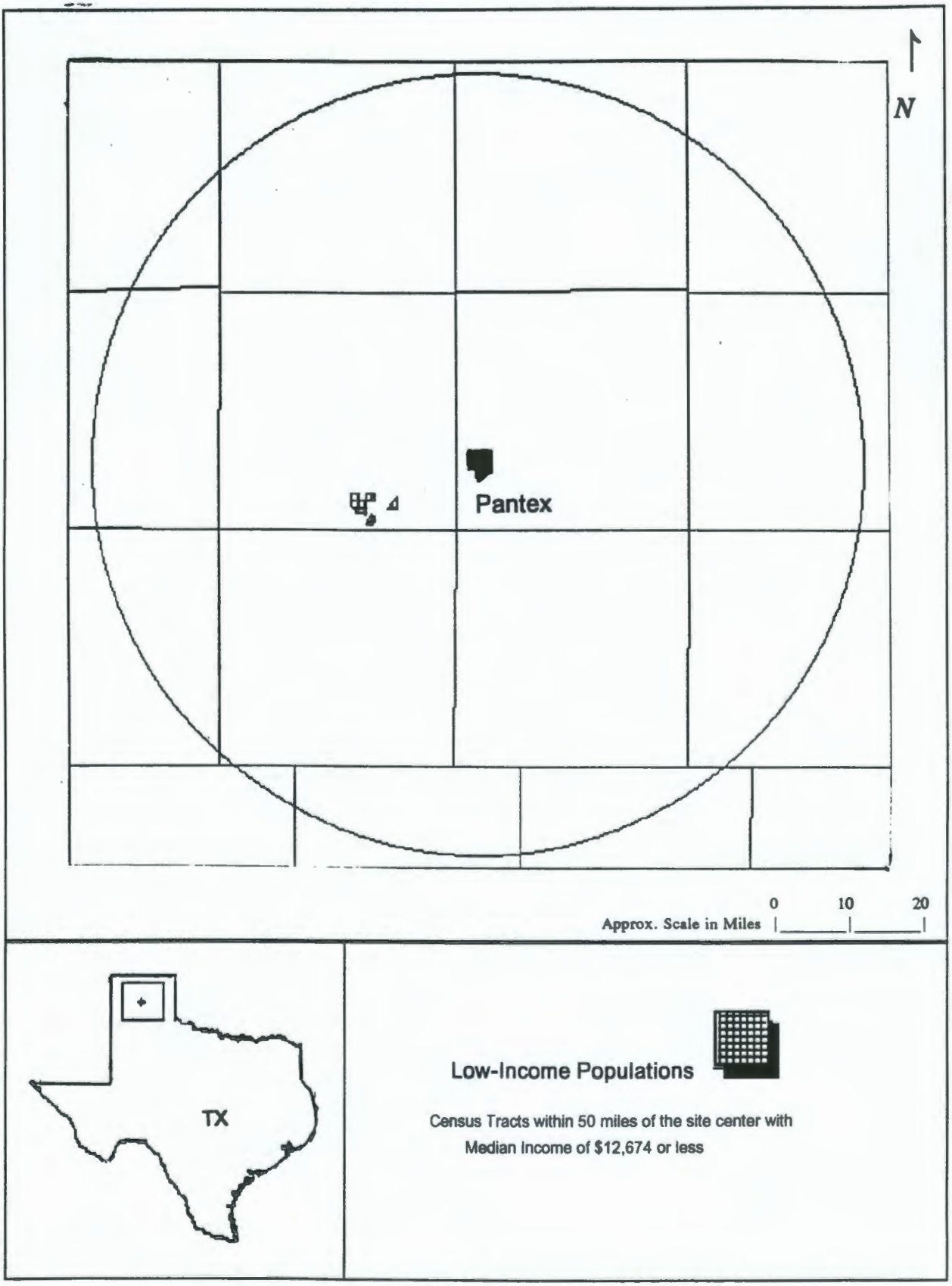

Figure I–28. Distribution of low-income populations at the Pantex Plant.

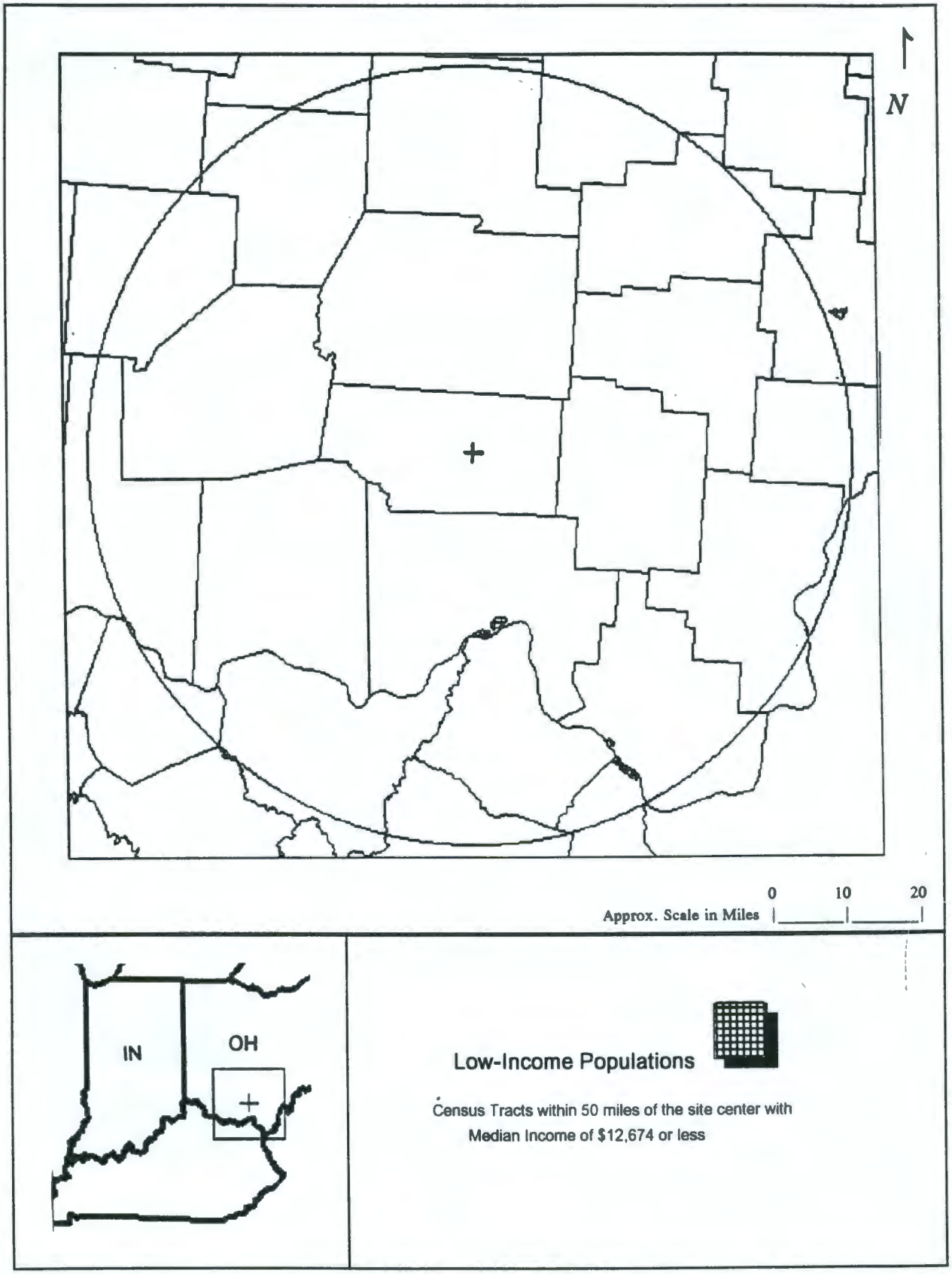

Figure I–29. Distribution of low-income populations at Portsmouth Gaseous Diffusion Plant.

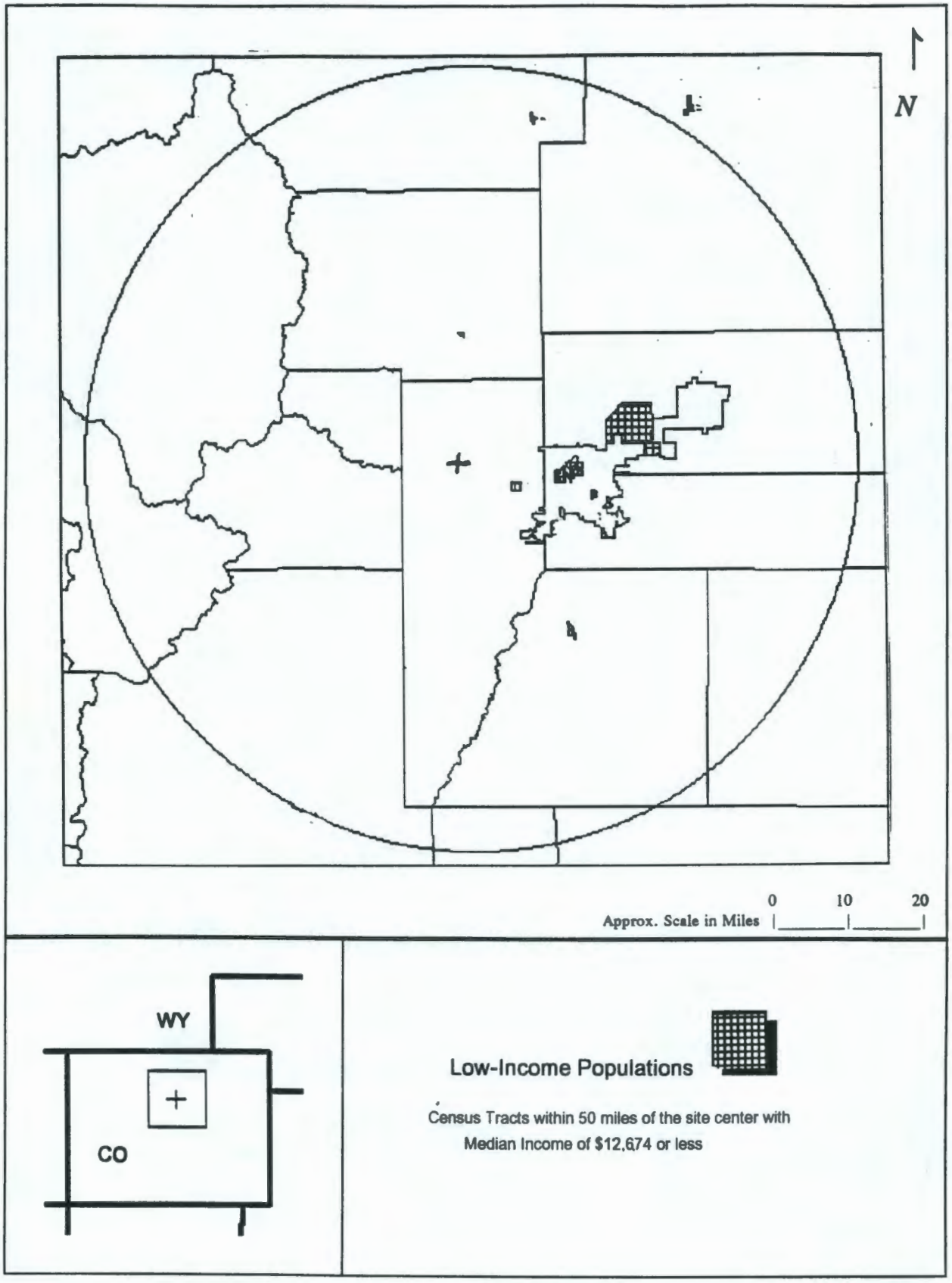

Figure I–30. Distribution of low-income populations at Rocky Flats Environmental Technology Site.

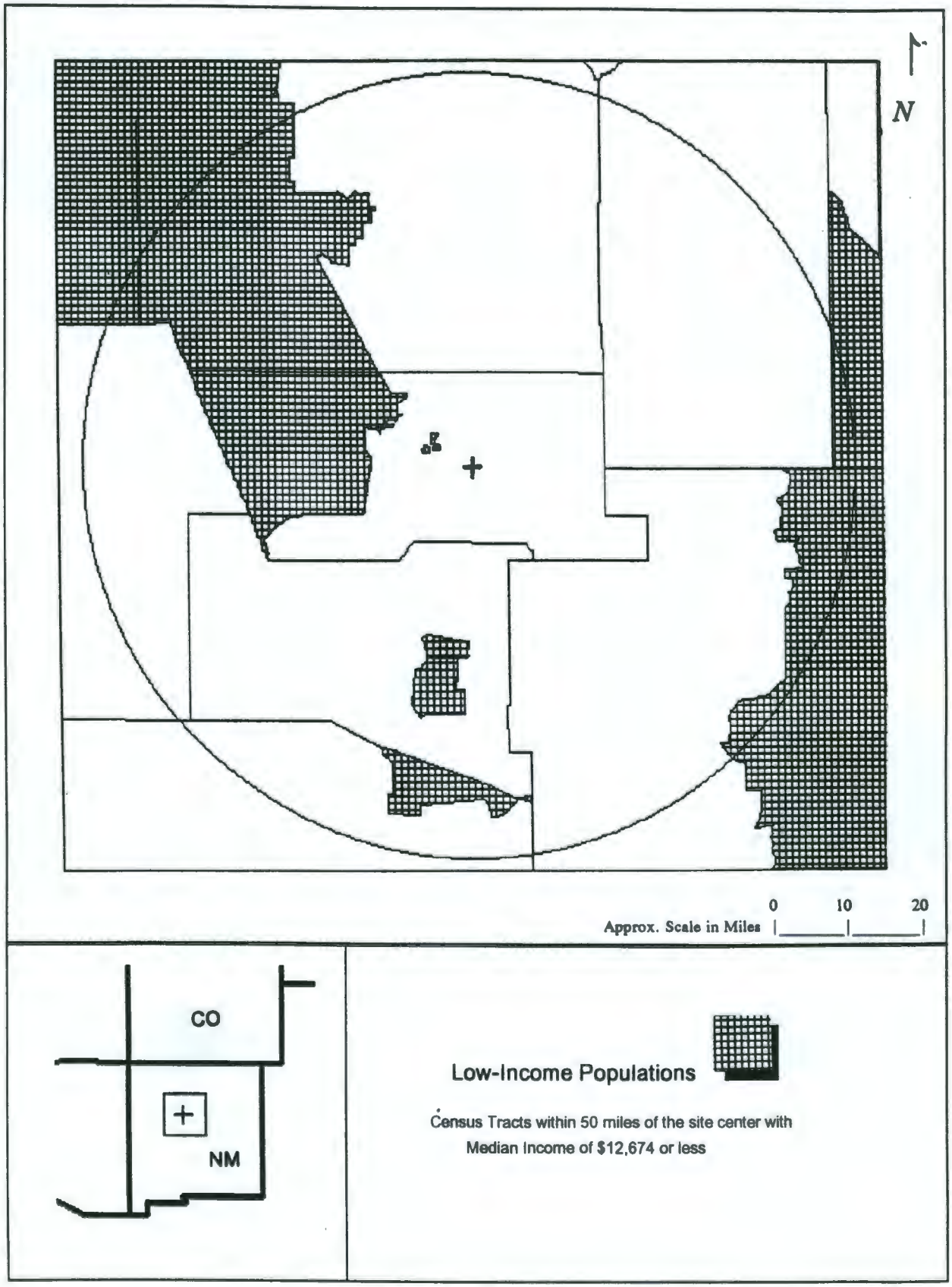

Figure I–31. Distribution of low-income populations at Sandia National Laboratory-New Mexico.

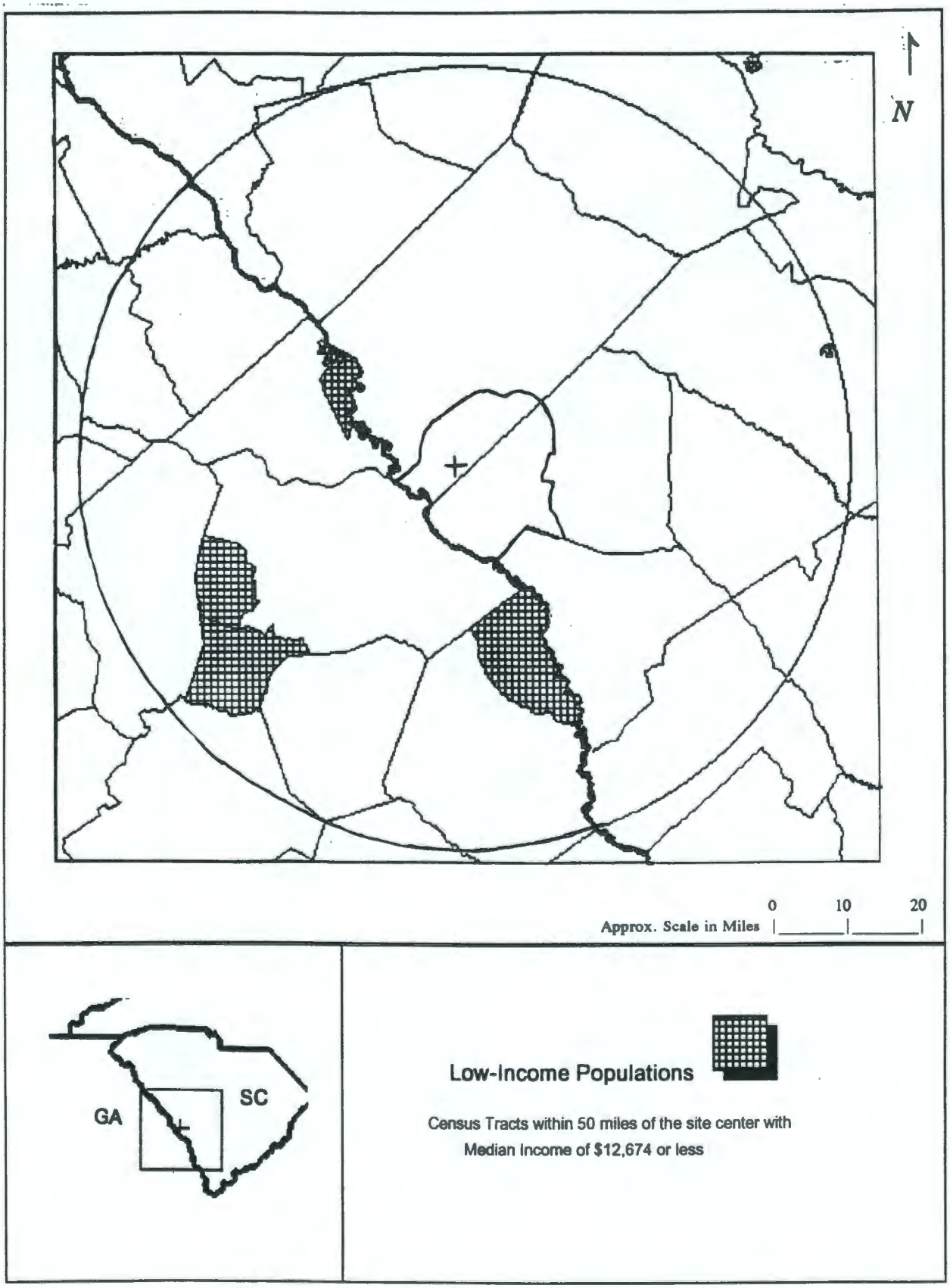

Figure I–32. Distribution of low-income populations at the Savannah River Site.

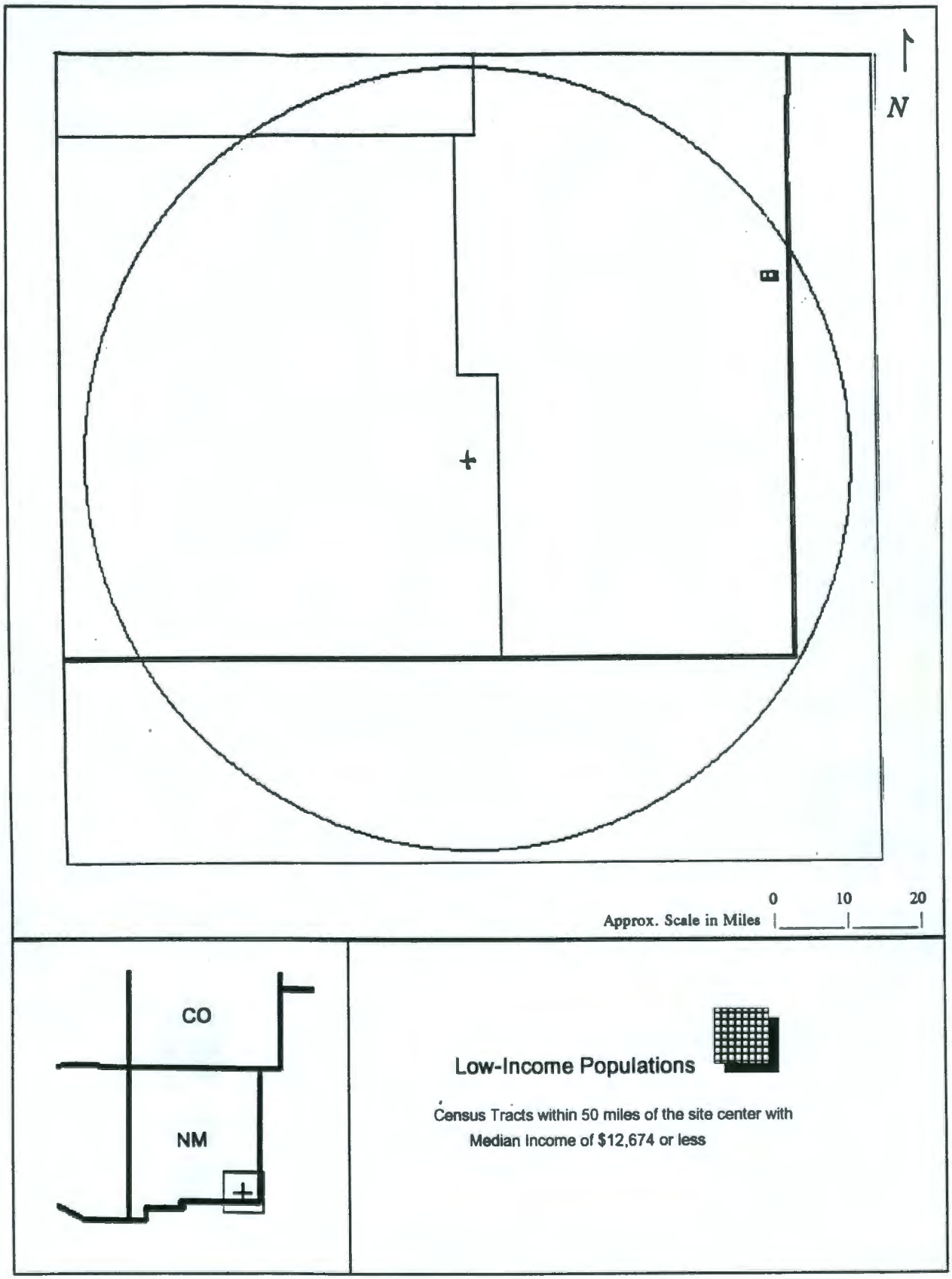

Figure I–33. Distribution of low-income populations at the Waste Isolation Pilot Plant.

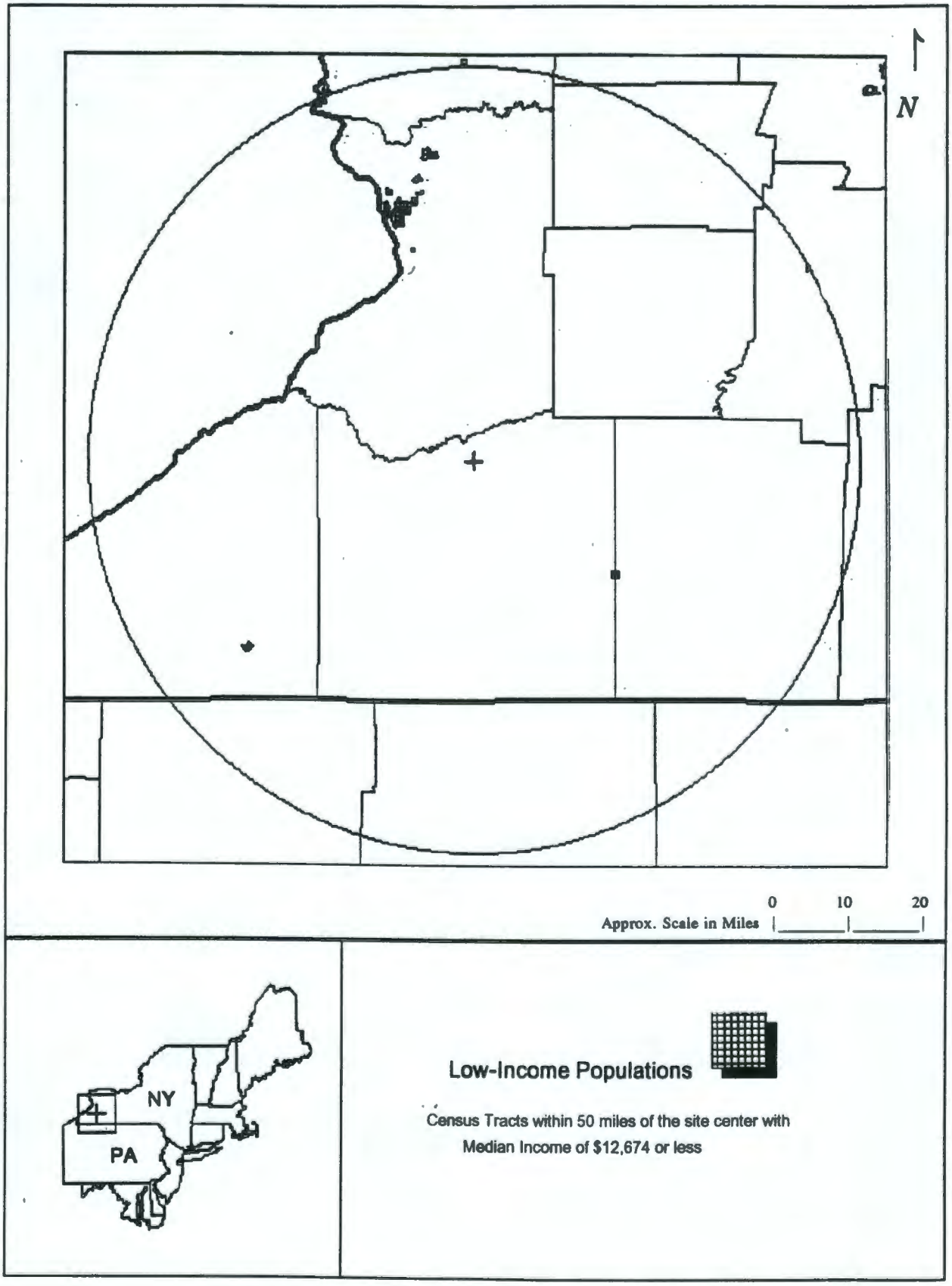

Figure I–34. Distribution of low-income populations at the West Valley Demonstration Project.