



Medical Isotopes Production Project: Molybdenum-99 and Related Isotopes

Environmental Impact Statement

Volume I

**U.S. Department of Energy
Office of Nuclear Energy,
Science and Technology
Washington, D.C.**

April 1996



COVER SHEET

RESPONSIBLE AGENCY:

U.S. Department of Energy

TITLE:

Medical Isotopes Production Project: Molybdenum-99 and Related Isotopes: Environmental Impact Statement, Volume I

CONTACT:

For further information on this document, write or call:

Mr. Wade Carroll, MIPP EIS Document Manager
Office of Nuclear Energy, Science and Technology, NE-70
U.S. Department of Energy
19901 Germantown Road
Germantown, Maryland 20874
Telephone: (301) 903-7731
Fax: (301) 903-5434

For further information on the Department's National Environmental Policy Act process, contact:

Ms. Carol M. Borgstrom, Director
Office of NEPA Policy and Assistance, EH-42
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585
Telephone: (202) 586-4600, or leave a message at (800) 472-2756

ABSTRACT:

This Environmental Impact Statement (EIS) provides environmental and technical information concerning the U.S. Department of Energy's (DOE) proposal to establish a domestic source to produce molybdenum-99 (Mo-99) and related medical isotopes (iodine-131, xenon-133 and iodine-125). Mo-99, a radioactive isotope of the element molybdenum, decays to form metastable technetium-99 (Tc-99m), a radioactive isotope used thousands of times daily in medical diagnostic procedures in the U.S. Currently, all Mo-99 used in the U.S. is obtained from a single Canadian source. DOE is pursuing the Medical Isotopes Production Project in order to ensure that a reliable supply of Mo-99 is available to the U.S. medical community. Under DOE's preferred alternative, the Chemistry and Metallurgy Research Facility at the Los Alamos National Laboratory (LANL) and the Annular Core Research Reactor and Hot Cell Facility at Sandia National Laboratories/New Mexico (SNL/NM) would be used for production of the medical isotopes.

In addition to the preferred alternative, three other reasonable alternatives and a no action alternative are analyzed in detail. The sites for the three reasonable alternatives are LANL, Oak Ridge National Laboratory (ORNL), and Idaho National Engineering Laboratory (INEL). The analyses in this EIS indicate no significant difference in the potential environmental impacts among the alternatives. Each of the alternatives would use essentially the same technology for the production of the medical isotopes. Minor differences in environmental impacts among alternatives relate to the extent of activity necessary to modify and restart (as necessary) existing reactors and hot cell facilities at each of the sites, the quantities of low-level radioactive waste generated, how such waste would be managed, and the length of time needed for initial and full production capacity.

DOE issued a Draft EIS on December 22, 1995, and held a formal public comment period on the draft through February 9, 1996. During the comment period, two public hearings were held at or near each of the four alternative locations. Comments received and DOE's responses to those comments are found in the second volume of this EIS. The Final EIS contains change bars in the left-hand margin, reflecting DOE's consideration of the public comments.



Department of Energy

Washington, DC 20585

Dear Reader:

This is your copy of the *Final Environmental Impact Statement (EIS) for the Medical Isotopes Production Project (MIPP): Molybdenum-99 and Related Isotopes*. The Final EIS analyzes the environmental impacts of the Department of Energy proposal to establish a domestic source to produce molybdenum-99 and related medical isotopes. In this review, the Department identified four reasonable alternatives for accomplishing the proposed action. The Department's preferred alternative is to use existing facilities at Sandia National Laboratories/New Mexico and Los Alamos National Laboratory with appropriate modifications.

The Final EIS is a two-volume document. Volume I contains a discussion of the purpose of and need for the proposed action, alternatives for accomplishing the proposed action, a description of the affected environment surrounding each reasonable alternative, an analysis of the potential environmental impacts associated with each alternative, and a discussion of the regulatory framework applicable to the proposed project. Volume II contains the public's comments on the Draft EIS and the Department's responses to those comments.

For additional copies of this document, please contact Mr. Wade Carroll, MIPP EIS Document Manager, Office of Nuclear Energy, Science and Technology, NE-70, U.S. Department of Energy, 19901 Germantown Road, Germantown, Maryland 20874-1290, telephone (301) 903-7731, facsimile (301) 903-5434.

The Department's decision on the proposed Medical Isotopes Production Project will be made after this EIS has been publicly available for at least 30 days. Thank you for your interest in this proposed project.

Sincerely,

A handwritten signature in black ink, which appears to read "Terry R. Lash", is positioned above the printed name.

Terry R. Lash, Director
Office of Nuclear Energy,
Science and Technology



Printed with soy ink on recycled paper

Summary

The U.S. Department of Energy (DOE) proposes to establish, as soon as practicable (in about 1 to 3 years), a domestic capability to produce a continuous supply of molybdenum-99 (Mo-99) and related medical isotopes for the U.S. medical community. The purpose of the proposed action is to ensure a reliable domestic supply of Mo-99, an important medical isotope, for the near term of 5 to 10 years.

The DOE has evaluated the following alternatives:

- No Action
- Annular Core Research Reactor: Sandia National Laboratories/New Mexico and Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory-Preferred Alternative
- Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory
- Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory
- Power Burst Facility/Test Area North: Idaho National Engineering Laboratory.

Purpose and Need for Action

Over the last four decades, DOE and its predecessor agencies have produced and distributed certain isotopes for medical and industrial applications through DOE's national laboratories. In 1990, Congress established the Isotope Production and Distribution Program to consolidate all existing DOE isotope production activities under one program. Among other activities, this program has responsibility for ensuring that the U.S. health care community has access to a reliable supply of Mo-99.

What is molybdenum-99? Mo-99 is a radioactive isotope of the element molybdenum. Mo-99 is produced by splitting (fissioning) uranium-235 or by otherwise modifying the nucleus of a stable isotope. Mo-99 decays to form metastable technetium-99 (Tc-99m), a radioactive isotope that has broad applications in the area of medical diagnostic procedures. Tc-99m is the most widely used medical radioisotope in the U.S. According to a study prepared for the U.S. House of Representatives Subcommittee on Energy and Environment in February 1995 by members of a group called the Senior Scientists and Engineers, it was estimated that a total of approximately 38,000 diagnostic procedures involving radioactive isotopes are performed each day in the U.S. Most of these procedures use Tc-99m.

By chemically attaching Tc-99m to different carrier agents, the isotope can be concentrated in specific parts of the body, such as the lungs, liver, heart, brain, and skeletal system, to help identify medical conditions in these areas that could otherwise be identified only through invasive surgery.

Both of these isotopes are very short-lived. Mo-99 and Tc-99m have half lives (the time in which the quantity of the isotope is reduced by 50 percent) of 66 hours and 6 hours, respectively. Therefore, production and distribution must be maintained on an essentially continuous basis with rapid processing and delivery.

How is molybdenum-99 produced? Either an accelerator, a solution-fueled nuclear reactor, or a solid-fueled nuclear reactor can be used to produce Mo-99. However, the most efficient way to produce Mo-99 is through the fissioning of uranium-235 in a nuclear reactor. Two processes currently have U.S. Food and Drug Administration (FDA) approval in the U.S. The first is used by Nordion International, a Canadian firm, and the second is the Cintichem process (named for the Cintichem corporation) to which DOE now owns the exclusive rights. Both of these processes involve the fissioning of uranium-235 within highly enriched uranium targets inserted into a solid-fueled reactor.

Who has produced molybdenum-99 in the U.S.? Development of the Mo-99/Tc-99m generator occurred at the Brookhaven National Laboratory in New York in the 1950s. The Atomic Energy Commission produced and supplied Mo-99 from its reactors at Oak Ridge National Laboratory, Tennessee, and Brookhaven National Laboratory, New York, until 1966 when it discontinued this service in deference to commercial sources which began producing Mo-99 in the U.S. Production of Mo-99 was initiated in 1966 by Union Carbide Nuclear Corporation. From 1970 until 1989, Mo-99 was produced privately in the U.S. by the Cintichem Corporation, using a company-owned nuclear reactor located at Tuxedo, New York. During that period, Cintichem supplied approximately half of the Mo-99 used in the U.S. In 1989, Cintichem decided to shut down and decommission the reactor. Since then, no Mo-99 provided to the U.S. medical community has been produced in the U.S.

What is the current U.S. source for molybdenum-99? Since the Cintichem reactor shut down, the U.S. medical community has been dependent entirely on Nordion International in Canada for Mo-99. Nordion supplies 100% of the U.S. demand and approximately 85% of the world demand for Mo-99. Nordion receives their bulk Mo-99 from a single nuclear reactor (the National Research Universal reactor) operated by Atomic Energy of Canada Limited at the Chalk River site approximately 100 miles northwest of Ottawa, Canada.

How is the U.S. vulnerable to interruption of Mo-99 supply? The Canadian reactor was commissioned in 1957. The Atomic Energy of Canada Limited plans to shut down the reactor in the year 2000. Nordion International and Atomic Energy of Canada Limited are exploring the possibility of constructing two new reactors and one new Mo-99 separation facility that could produce Mo-99 using an improved process. Plans for the new project continue to be discussed, but the official announcement to construct these facilities has not been made. If two reactors are built that can act as backup for each other, reliable and sufficient backup production capability is expected to exist. If only one reactor is built, the risk of relying

on a single source remains. To complete construction and commissioning of just one of these reactors and the required separation facility would take an estimated 36 months. By the end of commissioning, Nordion expects to have their new Mo-99 production process approved by the FDA. Completion of the construction and commissioning of the second reactor would take an estimated additional 12 months. Therefore, the earliest that Nordion could be expected to supply Mo-99 from a new reactor is mid-1999. Full-scale Mo-99 production would probably require at least an additional several months for each of the reactors. Until a backup production facility capable of providing 100% of the U.S. demand for Mo-99 is established, the U.S. will continue to be vulnerable to an interruption in the supply of this important isotope.

Are there other sources of molybdenum-99? Other Mo-99 production sources exist, located primarily in Europe. These sources potentially could increase their production rates in the event of a shut down of the Canadian reactor. Mo-99 could then be shipped to Nordion for final processing and shipment to radiopharmaceutical companies. However, due to the short half lives of Mo-99 and Tc-99m, the increased time required to ship Mo-99 from Europe would reduce the effective quantity of Mo-99 that could be supplied to the U.S. In any case, the European sources could supply only a portion of the U.S. demand. Accordingly, if the Canadian production source were to become unavailable, the supply of Mo-99 available to the U.S. would be substantially reduced or eliminated.

What is DOE's proposed action? DOE proposes to establish, as soon as practicable, a domestic capability to produce a continuous supply of Mo-99 and related medical isotopes for the U.S. medical community. The purpose of the proposed action is to ensure a reliable domestic supply of Mo-99, an important medical isotope. The near-term goal (over the next 5 to 10 years) would be to provide a backup capability for Mo-99 used in the U.S. by establishing a baseline production level of 10 to 30% of the current U.S. demand. This goal would include the capability to increase production to supply 100% of the U.S. demand, should the Canadian source become unavailable.

Because it is essential to establish a backup capacity as soon as possible, DOE proposes to use an FDA-approved Mo-99 production process. Specifically, DOE proposes to modify an existing research reactor and hot cells to produce and process Mo-99 and related medical isotopes. The Mo-99 would be packaged in Type B accident-resistant packaging for shipment by commercial air carriers to the U.S. radiopharmaceutical companies. Passenger aircraft could be used in accordance with the U.S. Department of Transportation regulation 49 CFR 175. The U.S. radiopharmaceutical companies would repackage the Mo-99 in Tc-99m generators from which the medical facilities would extract the Tc-99m. The U.S. radiopharmaceutical companies and their locations are as follows:

Company	Location
DuPont-Merck	Boston, Massachusetts
Amersham Medipysics	Chicago, Illinois
Mallinckrodt Medical	St. Louis, Missouri

The DOE may choose to ship the Mo-99 product from the selected site to Nordion in Canada in lieu of shipping the product directly to the radiopharmaceutical companies. The product would then be inserted into the Nordion process stream so that final product testing and distribution activities would be conducted by Nordion.

What are the related medical isotopes? The related medical isotopes that would be produced are iodine-125, iodine-131, and xenon-133. Iodine-125 and iodine-131 are used in the treatment of thyroid conditions, such as Graves disease. Xenon-133 is used in the diagnosis of lung maladies.

Iodine-131 and xenon-133, like Mo-99, are produced during the fission of uranium-235. These isotopes would be produced during the Mo-99 production process. Iodine-125 would be produced using a separate process. These isotopes could be produced under each of the Mo-99 production alternatives analyzed in detail in this EIS.

What has DOE recently done regarding molybdenum-99? In 1990, after Cintichem ceased production of Mo-99, the U.S. medical community and U.S. radiopharmaceutical industry asked DOE to plan for reestablishing a domestic production capability. The financial uncertainties involved in constructing a new nuclear reactor or operating an existing reactor to produce Mo-99 have thus far kept private companies from establishing a domestic Mo-99 production capability.

After an extensive review of government-owned operating reactors and facilities in 1991, the Omega West Reactor and the Chemistry and Metallurgy Research Facility at Los Alamos National Laboratory, New Mexico, were proposed as the preferred alternative for the U.S. production of Mo-99. However, in December of 1992, a leak was found in an underground coolant line of the Omega West Reactor. Subsequently, DOE identified the Annular Core Research Reactor at Sandia National Laboratories, New Mexico, and the Chemistry and Metallurgy Research Facility at Los Alamos National Laboratory as the preferred facilities for the production of Mo-99.

In 1994, DOE prepared an Environmental Assessment of Medical Isotope Production at Sandia National Laboratories, New Mexico, and Los Alamos National Laboratory. This predecisional draft was provided to the state of New Mexico and the public for comment in February of 1995. Based on the Environmental Assessment and on public comments received, DOE decided to prepare an environmental impact statement.

Changes from the Draft to the Final EIS

The Department released the Draft EIS for public comment in December 1995. The availability of the Draft EIS was announced by the Department in the December 22, 1995, issue of the *Federal Register* (60 FR 66542-66543). The public had a 49-day public comment period, which ended on February 9, 1996. Eight public hearings were held to give the public an opportunity to provide oral comments on the

Draft EIS. The hearings were held in Idaho Falls, Idaho on January 17, 1996; Oak Ridge, Tennessee on January 25, 1996; Albuquerque, New Mexico on January 30, 1996; and Los Alamos, New Mexico on February 1, 1996. Two hearings were held at each location.

A total of 61 individuals and organizations provided oral comments at the public hearings. In addition, the Department received 101 letters and written statements. Comments received on the Draft EIS were considered in preparing the Final EIS. Changes to the Draft EIS, either in response to public comment or to correct technical information, are denoted by a change bar in the margin. All comments received, along with the Department's responses to those comments, are reproduced in the Comment Response Document (Volume II of this EIS). Comments that resulted in notable changes to the EIS addressed the following topics:

- **Need for the Project** - Some commentors questioned why the Department has proposed to produce Mo-99 when other Mo-99 production initiatives (such as Nordion's plan to build the Maple I and II reactors) are planned or are underway. The Department further investigated these other Mo-99 production initiatives and, to reflect their current status, updated Sections 2.0 and 3.2.
- **The Preferred Alternative** - Multiple commentors questioned the viability of and the rationale for identifying the Annular Core Research Reactor at Sandia National Laboratories/New Mexico as the preferred alternative. Section 3.3.1.1 was revised to provide further insight into the Department's rationale for identifying the preferred alternative.
- **Cost of Alternatives** - Several commentors noted that the cost of the preferred alternative was not lowest among the four reasonable alternatives, and that the estimated cost for the Idaho and Oak Ridge alternatives should be further investigated. The EIS Team worked with the respective sites to develop additional cost data, and Section 5.22 has been revised to include this new data and to clarify the bases for the cost estimates.
- **Privatization of Mo-99 Production Facility** - Several commentors requested that the Department clarify its intent regarding the future privatization of any Mo-99 production capability that it may decide to establish. Section 2.0 has been revised to clarify the privatization discussion and to include a brief discussion of the Moly-99 project's relationship to the Department's National Isotope Strategy.
- **Shipment of Mo-99 to Nordion** - Organizations associated with the radiopharmaceutical industry commented that the Department should consider shipping Mo-99 to Nordion for final processing, quality assurance testing, and distribution. While shipment of Mo-99 to Nordion was included as a shipment option in the Draft EIS, the Summary, Section 5.11, and Appendix B of the Final EIS were modified to present this option more clearly.

- **Water Use** - Several organizations from New Mexico and other individual commentors questioned the wisdom of selecting Sandia National Laboratories/New Mexico as the preferred site, given recent reports that increased water use in the Albuquerque area could result in shortages and could even cause the city to sink (due to draining of the aquifer). Section 5.16 was revised to clarify and put into perspective the amount of water that would be used in the proposed project.
- **Required Modifications at the Power Burst Facility** - In response to comments from Idaho-based commentors, Section 3.3.4.9 was revised to clarify the modifications required to produce Mo-99 in the Power Burst Facility. These include modifications to the reactor central cavity, removal of transient control rods, and installation of coolant flow balance valves.
- **Site Descriptions** - Several commentors provided comments regarding the descriptions of the affected environment around the four sites under consideration. Chapter 4 was revised as appropriate to incorporate these comments.
- **Editorial Changes** - Multiple editorial changes were made to the EIS as a result of internal review and public comments.

Alternatives

What are the requirements for a molybdenum-99 production facility? In order to produce sufficient supplies of Mo-99 to meet 100% of the U.S. medical community demand, certain technical criteria must be met. For example, to minimize the current window of vulnerability, a reasonable alternative must be either an operating facility or one capable of operating in the near term. The production method used must allow the generation facility the capability to provide a quantity of approximately 3000 6-day curies per week to the radiopharmaceutical companies to satisfy 100% of the U.S. demand for Mo-99. (A 6-day curie is defined as the amount of product, in curies, remaining 6 days after the product is delivered to the radiopharmaceutical company.) Due to the need to maintain essentially continuous production, the facility's periodic scheduled maintenance outages must be reliably accomplished in no longer than 6 days. The facility operation must use an FDA-approved process for Mo-99 production. Finally, the facility must be able to package and transport irradiated targets to a separation facility that can chemically process the product.

What does a molybdenum-99 separation facility need? Certain technical criteria must be met for the facility to chemically process, separate, and purify Mo-99. Specifically, the facility must have enough shielded and sealed rooms (commonly known as hot cells) to support reliable Mo-99 separation (including separation and environmental control equipment, remote handling equipment, and a room for quality control). The facility must have adequate ventilation systems (separate zones, differential pressures, and filters) to handle any hazardous gases produced in either the production or separation process. Due to the

short half-life of Mo-99, the facility must be located in a place where timely packaging and shipment of the Mo-99 product from the facility will assure that purity and curie concentration requirements are met (10,000 curies of Mo-99 per gram of product upon delivery to the customer). The separation facility must be able to use an FDA-approved process for Mo-99 extraction. It must also be able to manage the radioactive waste that is generated during the processing.

How were the reasonable alternatives identified? A number of facilities were evaluated against the preliminary technical screening criteria for Mo-99 generation and processing. The alternatives considered for initial screening included each of the alternatives identified in the Notice of Availability for this environmental impact statement, as well as additional alternatives that had the potential to fulfill the Mo-99 production requirements. This preliminary screening provided the reasonable alternatives to be analyzed.

Which alternatives are evaluated in detail in the Environmental Impact Statement? The DOE evaluated the following reasonable alternatives:

- No Action
- Annular Core Research Reactor: Sandia National Laboratories/New Mexico and Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory-Preferred Alternative
- Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory
- Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory
- Power Burst Facility/Test Area North: Idaho National Engineering Laboratory.

What are the implications of the No Action alternative? Under this alternative, DOE would not establish a production capability for Mo-99 and related medical isotopes. The current U.S. demand for Mo-99 requires a weekly supply of approximately 3000 6-day curies of Mo-99. All Mo-99 sold in the U.S. is currently produced in Canada. Under the No Action alternative, the U.S. medical community would continue to rely on this source of supply. The Canadian reactor is nearly 40 years old and, although an aggressive maintenance program continues to keep the reactor operating, no plans have been made to continue operation beyond the year 2000. Under the No Action alternative, the following issues remain unresolved:

- The diagnostic procedure using Tc-99m, the daughter product of Mo-99, is the procedure of choice for the medical community. Without a reliable supply of Mo-99, invasive surgery may be the only alternative in many cases.

- The current reliance on a single source of Mo-99 creates the potential for the interruption of the Mo-99 supply.
- Sufficient replacement capacity cannot currently be established quickly in an emergency. A significant amount of planning time and resources is necessary to establish a Mo-99 production capability.
- The near-term production capacity in Europe is not sufficient to contribute significantly to the U.S. demand for an extended period of time.
- Reliable and sufficient backup capability (foreign or domestic) is not guaranteed in the foreseeable future.

Additionally, the financial risks for a private sector company to establish Mo-99 production are sufficiently high that, in the next several years, no domestic private sector company is expected to undertake Mo-99 production at a capacity sufficient to supply 100% of U.S. demand. Even assuming that a company accepts the risks, the estimated time to production precludes this option from consideration for near-term production.

If no action is taken by DOE to provide a domestic Mo-99 production capability, the U.S. medical community will continue to rely on the current Canadian source for Mo-99. Such a dependence will carry with it substantial risks for the foreseeable future. However, if the private sector company in Canada undertakes and completes construction of two reactors, sufficient backup production capability is expected to exist.

What would DOE do to minimize the U.S. vulnerability to interruption of Mo-99 supply? DOE would produce Mo-99 using the Cintichem process. As shown in Figure S-1, Mo-99 is produced using a stainless steel tube which is coated on the inside with highly enriched uranium (called a *target*). The target is irradiated in a small research size nuclear reactor for about a week. Each of the alternative reactors would initiate operations using existing fuel. Three of the alternatives (Annual Core Research Reactor, Omega West Reactor, and Oak Ridge Research Reactor) would initially use highly enriched uranium fuel.

The Power Burst Facility would use low enriched uranium fuel. All of the alternatives using highly enriched uranium would transition to the use of low enriched uranium fuel as the fuel is expended (expected to take between 1 to 7 years at 100% production). The conversion from highly enriched uranium to low enriched uranium for the three alternatives discussed would be a relatively simple and inexpensive undertaking. The irradiated target is transported to a shielded facility (hot cell). There the target is opened and the interior coating (that now contains Mo-99) is dissolved, removed, and processed. When the Mo-99 reaches a certain level of purity, it is packaged in a U.S. Department of Transportation-approved cask and shipped on commercial air carriers (a practice consistent with current isotope transportation modes) to radiopharmaceutical companies. A simplified production process is outlined in Figure S-1. Facilities that could be used in the production of Mo-99 by alternative are as follows.

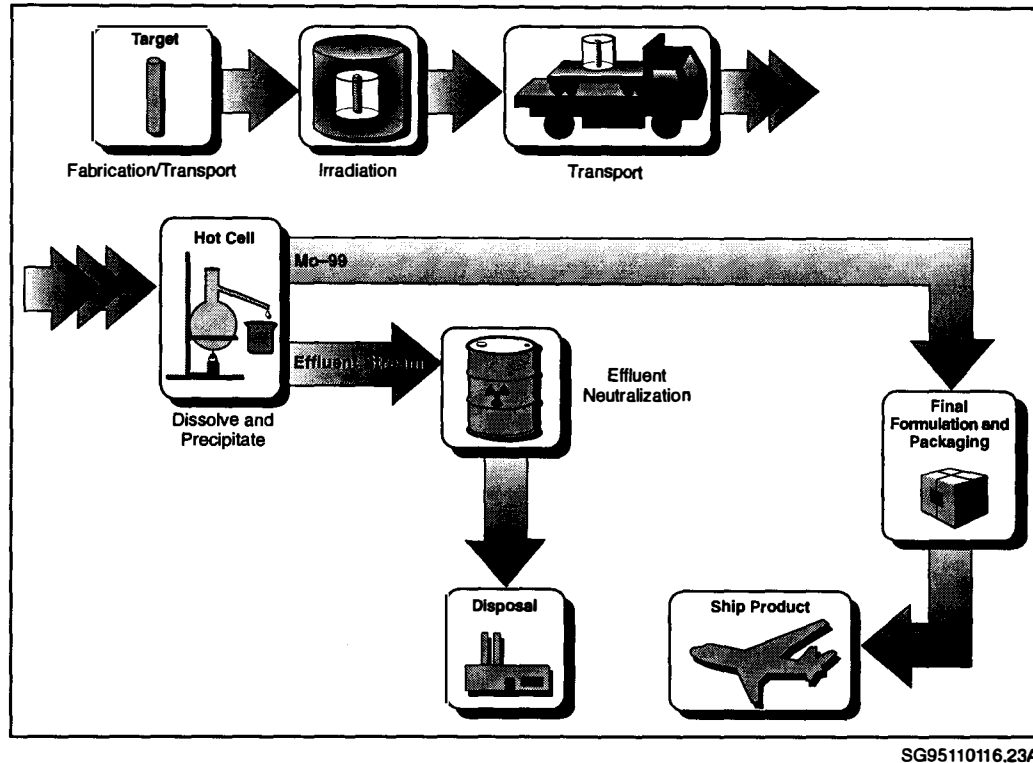


Figure S-1. Molybdenum-99 Production Process

Annular Core Research Reactor: Sandia National Laboratories/New Mexico and Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory

The Annular Core Research Reactor was identified as the preferred Mo-99 production alternative because it is a currently operating reactor, which would allow the shortest time to initial production and would reduce both cost and schedule uncertainties associated with producing Mo-99 and related medical isotopes. Targets would be fabricated at the LANL Chemistry and Metallurgy Research facility (preferred) or at SNL/NM. The targets would be irradiated in the Annular Core Research Reactor. The irradiated targets would be processed in the SNL/NM Hot Cell Facility to produce Mo-99 and related medical radioisotopes. Low-level radioactive wastes would be shipped to the Nevada Test Site for disposal.

Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory

The Chemistry and Metallurgy Research facility would be used for fabricating the targets and processing the targets to recover the Mo-99 and related isotopes. The targets would be irradiated in the Omega West Reactor, which would be repaired and restarted for this project. Low-level radioactive wastes would be disposed onsite at LANL.

Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory

The targets would be irradiated in the Oak Ridge Research Reactor which would be restarted for this project. The Radioisotope Development Laboratory would be used for fabricating the targets and processing the targets to recover Mo-99 and related isotopes. Low-level radioactive wastes would be shipped to the Nevada Test Site for disposal.

Power Burst Facility/Test Area North: Idaho National Engineering Laboratory

Targets would be fabricated at the INEL Test Area North, the Experimental Test Reactor Critical Facility annex, or the lower floor of the Materials Test Reactor building. The targets would then be shipped for irradiation to the Power Burst Facility, which is currently in standby and would need to be restarted. Targets would undergo processing either at hot cells at the Test Area North or in new hot cells constructed in a suitable location adjacent to the Power Burst Facility. Low-level radioactive wastes would be disposed onsite.

Which alternatives did not meet the screening criteria? Alternatives that did not meet the technical screening criteria were eliminated from further consideration. These alternatives, and a brief description of the reasons for their dismissal, are listed in Table S-1.

Table S-1. Alternatives Considered, But Dismissed

Alternative	Reason for Dismissal
INEL - Advanced Test Reactor	Operating characteristics, current mission
NIST Reactor/AFRRI Hot Cells	Current mission, unavailability, target contamination
One or More TRIGA Reactors	Hot cell availability, transportation, scheduling
ORNL - High Flux Isotope Reactor	Operating characteristics, current mission
ORNL - Bulk Shielding Reactor	Operating characteristics
Hanford - Fast Flux Test Facility	Facility size (too large), lack of other compatible missions, operating characteristics
Accelerator Facilities	Production capabilities
University Reactors	Individual production capabilities, lack of hot cells, conflicting missions, operational history
University of Missouri, Missouri Research Reactor Center	Mo-99 delivery capability, transportation problems, lack of hot cells, conflicting missions
Isotopes USA	Does not meet near-term goals; no advantage offered for near-term development of Mo-99 production
Babcock & Wilcox Medical Isotope Production Reactor	Does not meet near-term goals for Mo-99 production
Thermo Technology Ventures, Inc.	Does not meet near-term goals for Mo-99 production

Affected Environment

The EIS describes the environment that could be impacted by the proposed activities. The environments described are those surrounding the facilities at Sandia National Laboratories, New Mexico; Los Alamos National Laboratory, New Mexico; Oak Ridge National Laboratory, Tennessee; and Idaho National Engineering Laboratory, Idaho. No new major construction activities would be required under any of the reasonable alternatives. The facilities necessary to accomplish the proposed action exist at each of the alternative sites and would be available with minor modifications. Facility modifications identified as necessary to accomplish the proposed action are, for the most part, internal to the existing facilities. Consequently, the description of the affected environment emphasizes only those areas that are of most interest with respect to environmental consequences.

Environmental Consequences

What are the environmental consequences of the No Action alternative? The No Action alternative would not result in any additional environmental consequences. However, the consequences of the No Action alternative would be an increased risk to the U.S. health care community and its consumers. If the sole Canadian source of Mo-99 became unavailable for an extended time, cost of some diagnostic procedures and medical risk to patients would likely increase.

What are the environmental consequences of the reasonable alternatives? The analyses in this EIS indicate no significant difference in the environmental impacts among the alternatives. Each of the reasonable alternatives would use the same technology for the production of Mo-99 and related medical isotopes. Minor differences among the alternatives relate primarily to the type and status of the existing facilities, the modifications required to prepare the facilities for production, and amounts of low-level waste generated and how those wastes would be managed.

Under normal operating conditions, radiological doses to members of the public, involved and uninvolved workers from target fabrication and irradiation, product processing and transport for each of the alternatives would be well within regulatory limits established to protect human health. Each alternative would involve the use of an existing, small research reactor (10 MW thermal or less). The probability of credible accidents is low and the consequences of those accidents are small and would be similar for each site. The risk of latent cancer fatality would be very small under any of the alternatives.

Waste generated during the isotope production process would consist primarily of low-level radioactive waste. Each of the alternative sites has sufficient waste management capability either onsite or through existing arrangements with other DOE sites to dispose of low-level waste generated by the proposed activity. The quantities of spent nuclear fuel generated would be at most a few kilograms per year.

during production at rates sufficient to supply 100% of the U.S. demand. All alternative sites have adequate capabilities for storage of spent fuel for up to 5 years at a production rate sufficient to supply 100% of the U.S. demand. Community impacts resulting from project employment requirements are anticipated to be minimal. Impacts to cultural, ecological, and other natural environmental features would be negligible for any of the alternatives.

Table S-2 presents a comparison of the major environmental consequences of 100% production for reasonable alternatives analyzed in this EIS based on the analyses contained in Section 5.

Table S-2. Summary of Environmental Consequences and Comparison of Alternatives at 100% Production

Consequence Category	Unit of Measure	Alternatives			
		SNL/NM-ACRR LANL-CMR	LANL OWR/CMR	ORNL ORRR/RDL	INEL PBF/TAN
Air Quality					
Dose from Radionuclide Emissions to Air (normal operations)					
Offsite Maximally Exposed Individual	mrem/yr				
Target Irradiation		0.00017	0.15	0.004	0.0013
Target Processing		0.17	0.0042	0.31	0.13
Population within 80 km (50 mi)	person-rem/yr				
Target Irradiation		0.023	0.63	0.41	0.011
Target Processing		13	0.032	15	1.2
Risk of Latent Fatal Cancer(a)		0.007	0.0003	0.008	0.0006
Transportation					
Incident Free Transport (Annual Shipments of Targets, Products, and Waste)					
Radiological Dose	person-rem/yr				
Crew		24	23	23	23
Public		52	52	26	53
Risk of Latent Fatal Cancer ^(a)					
Crew		0.01	0.01	0.01	0.01
Public		0.03	0.03	0.01	0.03
Transportation Accidents (Ground and Air)					
Collective Public Risk from Accidents Involving Radioactive Materials:					
Risk of Latent Fatal Cancer ^(a)		2 x 10 ⁻⁵	2 x 10 ⁻⁵	1 x 10 ⁻⁵	2 x 10 ⁻⁵
Vehicle Accident Fatalities		0.01	0.01	0.02	0.01

Table S-2. (contd)

Consequence Category	Unit of Measure	Alternatives			
		SNL/NM-ACRR LANL-CMR	LANL OWR/CMR	ORNL ORRR/RDL	INEL PBF/TAN
Highest Consequence Facility Accidents					
Target Irradiation		Multiple Fuel Element Rupture	Fuel Melt	Fuel Melt	Fuel Melt
Accident Frequency	events per year	5 x 10 ⁻⁵	10 ⁻⁶ to 10 ⁻⁴	10 ⁻⁶ to 10 ⁻⁴	10 ⁻⁶ to 10 ⁻⁴
Dose to Offsite Maximally Exposed Individual	rem				
Inhalation/External ^(b)		0.076	0.48	0.037	0.099
All Pathways ^(b)		0.20	5.7	0.42	1.6
Dose to Population within 80 km (50 mi)	person-rem				
Inhalation/External ^(b)		150-2300	91 - 930	750 - 1400	20 - 170
All Pathways ^(b)		151-2350	91 - 940	5400 - 11000	900 - 7300
Latent Fatal Cancers (if accident occurs)		≤1	<1	<1 - 6	<1 - 4
Risk of Latent Fatal Cancer ^(a)		4 x 10 ⁻⁶ to 6 x 10 ⁻⁶	5 x 10 ⁻⁶	7 x 10 ⁻⁶ to 3 x 10 ⁻⁴	9 x 10 ⁻⁷ to 4 x 10 ⁻⁵
Resource Use - Operations					
Water	1000 m³/yr	40	120	120	120
Electricity	MWh/yr	400	500	500	500
Materials - Target Fabrication					
Highly Enriched (93 %) Uranium	kg/yr	4-36 ^(c)	3 ^(c)	3-26 ^(c)	3-26 ^(c)
Stainless Steel	tonnes/yr	0.50	0.36	0.36	0.36
Reactor Fuel					
Kilograms of Uranium Used in Fuel	kg U/yr	16	32	32	32
Spent Fuel Produced	elements/yr	57	29	22	17
SNF Storage Capacity	elements	300-1000 ^(d)	1091	984	786
Operational Wastes					
Low-level Radioactive Liquid	m³/yr	7.3 ^(e)	5.2 ^(e)	5.2 ^(e)	5.2
Low-level Radioactive Solid	m³/yr	49	17.6	68	80

Table S-2. (contd)

Consequence Category	Unit of Measure	Alternatives			
		SNL/NM-ACRR LANL-CMR	LANL OWR/CMR	ORNL ORRR/RDL	INEL PBF/TAN
Socioeconomics					
Primary Employment					
Construction/modifications	worker-years	92	92	113	97
Routine operations	workers	59	45	62	59
Cost					
Construction/modifications	million dollars	19.6	19.6	21.0 ^(f)	17.2 ^(f)
Routine operations (per year)	million dollars	12.8	11.0	9.6 ^(f)	8.4 ^(f)
(a) Radiological risk from normal operations or accidents is calculated as the latent cancer fatalities that might result if a radiological exposure occurred, multiplied by the estimated frequency of the event. The risk for normal operation assumes a frequency of 1.0 (that is, the exposure is assumed to occur), whereas the risk for accidents is estimated using the combined frequency of the accident and the assumed atmospheric conditions (if applicable) for a particular accident scenario. Where the risk of latent fatal cancer is less than 1, no cancers would be expected to result from a year of operation. (b) Accident consequences are conservative estimates that assume no protective actions are taken for offsite members of the public. The <i>Inhalation/External</i> pathway results correspond to a hypothetical release during a season when no agricultural products for human or animal consumption are growing. The <i>All Pathways</i> results correspond to a hypothetical release just before harvest, thereby maximizing the potential consequences of ingesting contaminated food. Neither analysis assumes protective action, such as evacuation, sheltering, or interdiction of contaminated food products, for the public. (c) Minimum values assume 90% recovery of highly enriched uranium after isotope extraction. Uranium recovery would occur at LANL, and could be implemented at other sites. However, the consequence analyses presented in Section 5 do not assume uranium recovery at sites other than LANL. Unrecovered highly enriched uranium would go into the waste stream and is included in the waste volume presented for sites other than LANL. (d) 300 is current capability; 1000 is potential capability (cost not included). (e) Liquid waste volumes are before solidification. Liquid wastes would be solidified at indicated sites prior to disposal. (f) As explained in Section 5.22, the cost estimates for ORNL and INEL are expected to contain greater uncertainties than those presented for SNL/NM and LANL.					
ACRR - Annular Core Research Reactor CMR - Chemistry and Metallurgy Research Facility ORRR - Oak Ridge Research Reactor OWR - Omega West Reactor PBF - Power Burst Facility RDL - Radioisotope Development Laboratory TAN - Test Area North					

Contents

Summary	iii
Acronyms and Abbreviations	xxxiv
Units of Measure	xxxix
Nomenclature	xl
Conversion Table	xlii
Element and Chemical Nomenclature	xliii
Radionuclide Nomenclature	xliv
1.0 Introduction	1.1
1.1 Organization	1.1
1.2 Alternatives Analyzed	1.2
1.3 Laws and Regulations	1.3
1.4 Public Participation and Outreach	1.3
1.4.1 Public Participation Outreach	1.3
1.4.2 Changes from the Draft EIS	1.7
1.5 Next Steps	1.8
1.6 Relationship of the MIPP-EIS to Other DOE NEPA Documents	1.8
2.0 Purpose and Need for Action	2.1
3.0 Alternatives	3.1
3.1 Approach to Determine the Reasonable Alternatives	3.1
3.1.1 Molybdenum-99 Production Facility(ies) Needs	3.1
3.1.2 Molybdenum-99 Separation Facility Needs	3.1
3.2 No Action Alternative	3.4
3.2.1 Description of the Alternative	3.4
3.2.2 Impacts of the No Action Alternative	3.5
3.3 Alternatives to Accomplish the Proposed Action	3.8
3.3.1 Annular Core Research Reactor: Sandia National Laboratories/New Mexico And the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative--Preferred Alternative	3.8
3.3.1.1 Description of the Alternative	3.8
3.3.1.2 Existing Facilities	3.10
3.3.1.3 Target Fabrication	3.10
3.3.1.4 Target Irradiation Activities at the Annular Core Research Reactor	3.15
3.3.1.5 Target Transfer to Hot Cell Facility	3.16
3.3.1.6 Isotope Extraction at Hot Cell Facility	3.18
3.3.1.7 Product Shipment	3.20
3.3.1.8 Waste and Spent Nuclear Fuel Management	3.20
3.3.1.9 Required Modifications	3.21
3.3.1.10 Estimated Schedule for Modification	3.27

3.3.2	Omega West Reactor/Chemistry and Metallurgy Research Facility:	
	Los Alamos National Laboratory Alternative	3.27
3.3.2.1	Description of the Alternative	3.29
3.3.2.2	Existing Facilities	3.29
3.3.2.3	Target Fabrication	3.29
3.3.2.4	Target Irradiation Activities	3.30
3.3.2.5	Target Transfer to the Hot Cell Facilities	3.33
3.3.2.6	Isotope Extraction at Hot Cell Facility	3.33
3.3.2.7	Product Shipment	3.35
3.3.2.8	Waste and Spent Nuclear Fuel Management	3.35
3.3.2.9	Required Modifications	3.36
3.3.2.10	Estimated Schedule for Modification	3.37
3.3.3	Oak Ridge Research Reactor/Radioisotope Development Laboratory:	
	Oak Ridge National Laboratory Alternative	3.37
3.3.3.1	Description of the Alternative	3.37
3.3.3.2	Existing Facilities	3.37
3.3.3.3	Target Fabrication at ORNL	3.37
3.3.3.4	Target Irradiation Activities	3.38
3.3.3.5	Target Transfer to the Hot Cell Facility	3.39
3.3.3.6	Isotope Extraction at the Hot Cell Facility	3.40
3.3.3.7	Product Shipment	3.42
3.3.3.8	Waste and Spent Nuclear Fuel Management	3.42
3.3.3.9	Required Modifications	3.42
3.3.3.10	Estimated Schedule for Modification	3.43
3.3.4	Power Burst Facility/Test Area North: Idaho National Engineering	
	Laboratory Alternative	3.43
3.3.4.1	Description of the Alternative	3.43
3.3.4.2	Existing Facilities	3.44
3.3.4.3	Target Fabrication at INEL	3.44
3.3.4.4	Target Irradiation Activities	3.44
3.3.4.5	Target Transfer to the Hot Cell Facility	3.46
3.3.4.6	Isotope Extraction at the Hot Cell Facility	3.46
3.3.4.7	Product Shipment	3.47
3.3.4.8	Waste and Spent Nuclear Fuel Management	3.47
3.3.4.9	Required Modifications	3.47
3.3.4.10	Estimated Schedule for Modification	3.49
3.4	Alternatives Considered and Dismissed	3.49
3.4.1	Other Federal Facilities	3.49
3.4.1.1	Advanced Test Reactor - Idaho National Engineering Laboratory	3.49
3.4.1.2	National Institute of Standards and Technology Reactor/Armed Forces Radiobiology Research Institute Hot Cell Facilities	3.50
3.4.1.3	One or More TRIGA Reactors	3.51
3.4.1.4	High Flux Isotope Reactor - Oak Ridge	3.53
3.4.1.5	Bulk Shielding Reactor - Oak Ridge	3.53
3.4.1.6	Fast Flux Test Facility - Hanford	3.53
3.4.1.7	Accelerator Facilities - Los Alamos and Others	3.54

3.4.2	University Reactors	3.56
3.4.2.1	University of Missouri Research Reactor	3.56
3.4.2.2	Other University Reactors	3.58
3.4.3	Other Public/Private Options	3.59
3.4.3.1	Isotopes U.S.A.	3.59
3.4.3.2	Babcock and Wilcox Medical Isotope Production Reactor	3.60
3.4.3.3	Thermo Technology Ventures, Inc.	3.60
3.5	Comparison of Alternatives	3.60
4.0	Affected Environment	4.1
4.1	Sandia National Laboratories—Albuquerque	4.1
4.1.1	Overview	4.1
4.1.2	Land Use	4.3
4.1.2.1	Albuquerque Area	4.3
4.1.2.2	Sandia National Laboratories	4.3
4.1.2.3	Technical Area V	4.5
4.1.3	Socioeconomic Environment	4.5
4.1.3.1	Demographic Characteristics	4.5
4.1.3.2	Economic Base	4.5
4.1.4	Cultural Resources	4.7
4.1.5	Aesthetic and Scenic Resources	4.7
4.1.6	Geologic Resources	4.7
4.1.6.1	General Geology	4.7
4.1.6.2	Mineral Resources	4.9
4.1.6.3	Site Stability	4.9
4.1.7	Air Quality	4.10
4.1.7.1	Nonradiological Air Quality	4.10
4.1.7.2	Radiological Air Quality	4.10
4.1.8	Water Quality	4.12
4.1.8.1	Surface Water	4.12
4.1.8.2	Groundwater	4.12
4.1.9	Ecological Resources	4.12
4.1.9.1	Terrestrial Resources	4.12
4.1.9.2	Aquatic Resources	4.13
4.1.9.3	Wetlands	4.13
4.1.9.4	Threatened and Endangered Species	4.13
4.1.10	Noise	4.13
4.1.11	Transportation	4.14
4.1.11.1	Roadways	4.14
4.1.11.2	Airports and Air Traffic	4.15
4.1.12	Radiological Public Health and Safety	4.16
4.1.12.1	Current Radiological Environment	4.16
4.1.12.2	Present Radiological Exposures of Workers in Technical Area V	4.17
4.1.13	Site Services	4.18
4.1.14	Waste and Spent Nuclear Fuel Management	4.19
4.1.14.1	Introduction	4.19

4.1.14.2 Spent Nuclear Fuel	4.19
4.1.14.3 Low-Level Waste	4.19
4.1.14.4 Low-Level Mixed Waste	4.19
4.2 Los Alamos Environment	4.20
4.2.1 Overview	4.20
4.2.2 Land Use	4.21
4.2.2.1 Los Alamos National Laboratory	4.21
4.2.2.2 Technical Area-2	4.21
4.2.2.3 Technical Area-3	4.24
4.2.3 Socioeconomic Environment	4.24
4.2.3.1 Demographic Characteristics	4.25
4.2.3.2 Economic Base	4.25
4.2.4 Cultural Resources	4.25
4.2.5 Aesthetic and Scenic Resources	4.26
4.2.6 Geologic Resources	4.26
4.2.6.1 General Geology	4.28
4.2.6.2 Mineral Resources	4.30
4.2.6.3 Site Stability	4.30
4.2.7 Air Quality	4.30
4.2.7.1 Nonradiological Air Quality	4.31
4.2.7.2 Radiological Air Quality	4.32
4.2.8 Water Quality	4.32
4.2.8.1 Surface Water	4.32
4.2.8.2 Groundwater	4.34
4.2.9 Ecological Resources	4.34
4.2.9.1 Terrestrial Resources	4.35
4.2.9.2 Aquatic Resources	4.35
4.2.9.3 Wetlands	4.35
4.2.9.4 Threatened and Endangered Species	4.38
4.2.10 Noise	4.38
4.2.11 Transportation	4.38
4.2.11.1 Roadways	4.38
4.2.11.2 Airports and Air Traffic	4.41
4.2.12 Radiological Health and Safety	4.41
4.2.12.1 Current Radiological Environment	4.41
4.2.13 Site Services	4.44
4.2.14 Waste and Spent Nuclear Fuel Management	4.45
4.2.14.1 Spent Nuclear Fuel	4.45
4.2.14.2 Low-Level Waste	4.45
4.2.14.3 Low-Level Mixed Waste	4.45
4.3 Oak Ridge Environment	4.46
4.3.1 Overview	4.46
4.3.2 Land Use	4.48
4.3.2.1 Oak Ridge Reservation	4.49
4.3.2.2 Oak Ridge National Laboratory	4.49
4.3.3 Socioeconomic Environment	4.49

4.3.3.1 Demographic Characteristics	4.49
4.3.3.2 Economic Base	4.51
4.3.4 Cultural Resources	4.51
4.3.5 Aesthetic and Scenic Resources	4.52
4.3.6 Geologic Resources	4.53
4.3.6.1 General Geology	4.53
4.3.6.2 Mineral Resources	4.54
4.3.6.3 Site Stability	4.54
4.3.7 Air Quality	4.55
4.3.7.1 Nonradiological Air Quality	4.55
4.3.7.2 Radiological Air Quality	4.56
4.3.8 Water Quality	4.56
4.3.8.1 Surface Water	4.56
4.3.8.2 Groundwater	4.58
4.3.9 Ecological Resources	4.58
4.3.9.1 Terrestrial Resources	4.58
4.3.9.2 Aquatic Resources	4.59
4.3.9.3 Wetlands	4.59
4.3.9.3 Threatened and Endangered Species	4.59
4.3.9.4 Threatened and Endangered Species	4.60
4.3.10 Noise	4.60
4.3.11 Transportation	4.60
4.3.11.1 Roadways	4.63
4.3.11.2 Airports and Air Traffic	4.63
4.3.12 Radiological Health and Safety	4.63
4.3.13 Site Services	4.65
4.3.14 Waste and Spent Nuclear Fuel Management	4.65
4.3.14.1 Spent Nuclear Fuel	4.66
4.3.14.2 Low-Level Radioactive Waste	4.66
4.3.14.3 Low-Level Mixed Waste	4.67
4.4 Idaho Falls Environment	4.67
4.4.1 Overview	4.68
4.4.2 Land Use	4.69
4.4.2.1 Regional Area	4.69
4.4.2.2 Idaho National Engineering Laboratory	4.69
4.4.2.3 Power Burst Facility	4.71
4.4.3 Socioeconomic Environment	4.72
4.4.3.1 Demographic Characteristics	4.72
4.4.3.2 Economic Base	4.73
4.4.4 Cultural Resources	4.74
4.4.5 Aesthetic and Scenic Resources	4.74
4.4.6 Geologic Resources	4.75
4.4.6.1 General Geology	4.74
4.4.6.2 Mineral Resources	4.76
4.4.6.3 Site Stability	4.76
4.4.7 Air Quality	4.79

4.4.7.1 Nonradiological Air Quality	4.79
4.4.7.2 Radiological Air Quality	4.79
4.4.8 Water Quality	4.81
4.4.8.1 Surface Water	4.81
4.4.8.2 Groundwater	4.81
4.4.9 Ecological Resources	4.82
4.4.9.1 Terrestrial Resources	4.82
4.4.9.2 Aquatic Resources	4.82
4.4.9.3 Wetlands	4.83
4.4.9.4 Threatened and Endangered Species	4.83
4.4.10 Noise	4.83
4.4.11 Transportation	4.83
4.4.11.1 Roadways	4.83
4.4.11.2 Airports and Air Traffic	4.86
4.4.12 Radiological Health and Safety	4.86
4.4.13 Site Services	4.88
4.4.14 Waste and Spent Nuclear Fuel Management	4.89
4.4.14.1 Spent Nuclear Fuel	4.90
4.4.14.2 Low-Level Radioactive Waste	4.90
4.4.14.3 Low-Level Mixed Waste	4.90
5.0 Environmental Consequences	5.1
5.1 Overview	5.1
5.2 Land Use	5.2
5.3 Socioeconomics	5.3
5.4 Cultural Resources	5.5
5.5 Aesthetic and Scenic Resources	5.6
5.6 Geologic Resources	5.6
5.7 Air Quality	5.6
5.7.1 Annular Core Research Reactor: Sandia National Laboratories/New Mexico and the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative	5.8
5.7.2 Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative	5.9
5.7.3 Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory Alternative	5.11
5.7.4 Power Burst Facility/Test Area North: Idaho National Engineering Laboratory Alternative	5.11
5.8 Water Quality	5.12
5.9 Ecological Resources	5.13
5.10 Noise	5.13
5.11 Transportation	5.13
5.11.1 Methods and Assumptions	5.13
5.11.1.1 Shipping Scenarios	5.14
5.11.1.2 Shipping System Descriptions	5.15
5.11.1.3 Transportation Route Information	5.16

5.11.2	Routine or Incident-Free Transportation Impacts	5.16
5.11.2.1	Radiological Impacts from Transportation Activities	5.16
5.11.2.2	Nonradiological Impacts from Transportation Activities	5.20
5.11.3	Transportation Accident Impacts	5.20
5.11.3.1	Radiological Impacts Due to Transportation Accidents	5.21
5.11.3.2	Nonradiological Impacts from Transportation Accidents	5.22
5.12	Occupational and Public Health and Safety	5.23
5.12.1	Radiological Consequences to Members of the Public	5.23
5.12.2	Radiological Consequences to Workers	5.24
5.12.3	Nonradiological Consequences	5.25
5.13	Site Services and Resources	5.26
5.13.1	Annular Core Research Reactor: Sandia National Laboratories/New Mexico and the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative	5.26
5.13.1.1	Modifications at LANL for Target Fabrication	5.26
5.13.1.2	Modifications at SNL/NM Hot Cell Facilities	5.27
5.13.1.3	Annular Core Research Reactor Facility Modifications at SNL/NM	5.27
5.13.1.4	Hot Cell Facility Modifications	5.27
5.13.1.5	Operational Resources Required	5.28
5.13.2	Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative	5.29
5.13.2.1	Materials Required for Omega West Reactor Upgrades	5.29
5.13.2.2	Operational Resources Required	5.29
5.13.3	Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory Alternative	5.29
5.13.3.1	Oak Ridge Research Reactor Facility Modifications	5.29
5.13.3.2	Mo-99 Processing Facility Modifications	5.29
5.13.3.3	Operational Resources Required	5.30
5.13.4	Power Burst Facility/Test Area North: Idaho National Engineering Laboratory Alternative	5.30
5.13.4.1	Power Burst Facility Modifications	5.30
5.13.4.2	Hot Cell Facility Modifications	5.30
5.13.4.3	Operational Resources Required	5.30
5.14	Waste and Spent Nuclear Fuel Management	5.31
5.14.1	Annular Core Research Reactor: Sandia National Laboratories/New Mexico and the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Preferred Alternative	5.31
5.14.1.1	Waste Generation from Medical Isotope Production	5.31
5.14.1.2	Waste Disposal	5.34
5.14.1.3	Target Fabrication/Annular Core Research Reactor Irradiation: Sandia National Laboratories/New Mexico Alternative	5.34
5.14.2	Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative	5.36
5.14.3	Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory Alternative	5.37

5.14.4	Power Burst Facility/Target Fabrication: Idaho National Engineering Laboratory Alternative	5.38
5.14.5	Comparison to Current Waste Generation Rates	5.39
5.15	Facility Accidents	5.39
5.15.1	Annular Core Research Reactor: Sandia National Laboratories/New Mexico and the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative	5.43
5.15.1.1	Target Fabrication at LANL	5.43
5.15.1.2	Target Fabrication at SNL/NM	5.44
5.15.1.3	Facility Accidents for Target Irradiation at the Annular Core Research Reactor	5.45
5.15.1.4	Transfer of Irradiated Target from the Annular Core Research Reactor to the Hot Cell Facility	5.48
5.15.1.5	Target Processing at SNL/NM Hot Cell Facilities	5.51
5.15.2	Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative	5.53
5.15.2.1	Target Fabrication at the Chemistry and Metallurgy Research Facility	5.53
5.15.2.2	Target Irradiation at the Omega West Reactor - Air Release Scenarios	5.53
5.15.2.3	Target Irradiation at the Omega West Reactor - Liquid Release Scenario ..	5.55
5.15.2.4	Target Irradiation at the Omega West Reactor - Flooding Potential	5.56
5.15.2.5	Target Irradiation at the Omega West Reactor - Falling Boulders	5.56
5.15.2.6	Target Transfer from the Omega West Reactor to the Chemistry and Metallurgy Research Facility	5.57
5.15.2.7	Target Processing at the Chemistry and Metallurgy Research Facility	5.57
5.15.3	Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory Alternative	5.60
5.15.3.1	Target Fabrication at Oak Ridge National Laboratory Hot Cells	5.60
5.15.3.2	Target Irradiation at Oak Ridge Research Reactor	5.60
5.15.3.3	Target Transfer from the Oak Ridge Research Reactor to the Hot Cells	5.61
5.15.3.4	Target Processing at Oak Ridge National Laboratory Hot Cells	5.63
5.15.4	Power Burst Facility/Test Area North: Idaho National Engineering Laboratory Alternative	5.64
5.15.4.1	Target Fabrication at Test Area North Hot Cells	5.64
5.15.4.2	Target Irradiation at the Power Burst Facility	5.64
5.15.4.3	Target Transfer from the Power Burst Facility to Hot Cells	5.66
5.15.4.4	Target Processing	5.67
5.15.5	Nonradiological Accidents	5.68
5.15.6	Secondary Impacts of Accidents	5.69
5.16	Cumulative Impacts	5.70
5.16.1	Annular Core Research Reactor: Sandia National Laboratories/New Mexico and the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative	5.71
5.16.1.1	Site Services and Resource Use	5.71
5.16.1.2	Waste Management	5.71
5.16.1.3	Air Quality	5.72
5.16.1.4	Occupational Health and Safety	5.72

5.16.2	Omega West Reactor/Chemistry and Metallurgy Research Facility:	
	Los Alamos National Laboratory Alternative	5.72
5.16.2.1	Site Services and Resource Use	5.72
5.16.2.2	Waste Management	5.73
5.16.2.3	Air Quality	5.73
5.16.2.4	Occupational Health and Safety	5.73
5.16.3	Oak Ridge Research Reactor/Radioisotope Development Laboratory:	
	Oak Ridge National Laboratory Alternative	5.74
5.16.3.1	Site Services and Resource Use	5.74
5.16.3.2	Waste Management	5.74
5.16.3.3	Air Quality	5.74
5.16.3.4	Occupational Health and Safety	5.75
5.16.4	Power Burst Facility/Test Area North: Idaho National Engineering	
	Laboratory Alternative	5.75
5.16.4.1	Site Services and Resource Use	5.75
5.16.4.2	Waste Management	5.76
5.16.4.3	Air Quality	5.76
5.16.4.4	Occupational Health and Safety	5.76
5.16.5	Cumulative Impacts of Transportation	5.76
5.17	Unavoidable Adverse Environmental Impacts	5.77
5.18	Relationship Between Short-Term Uses of the Environment and the Maintenance	
	and Enhancement of Long-Term Productivity	5.77
5.19	Irreversible and Irretrievable Commitment of Resources	5.78
5.20	Potential Mitigation Measures	5.80
5.21	Environmental Justice	5.80
5.21.1	Annular Core Research Reactor: Sandia National Laboratories/New Mexico	
	and the Chemistry and Metallurgy Research Facility: Los Alamos National	
	Laboratory Alternative	5.81
5.21.2	Omega West Reactor/Chemistry and Metallurgy Research Facility:	
	Los Alamos National Laboratory Alternative	5.86
5.21.3	Oak Ridge Research Reactor/Radioisotope Development Laboratory:	
	Oak Ridge National Laboratory Alternative	5.90
5.21.4	Power Burst Facility/Test Area North: Idaho National Engineering	
	Laboratory Alternative	5.94
5.22	Costs	5.97
6.0	Regulatory Framework	6.1
6.1	Radiological Safety Oversight	6.1
6.2	Food and Drug Administration Approvals	6.3
6.3	Transportation Requirements	6.3
6.4	Occupational Safety and Radiation Exposure	6.4
6.5	Radiation Exposure to Members of the Public	6.4
6.6	Noise	6.5
6.7	Floodplains and Wetlands	6.5
6.8	Species Protection	6.5
6.9	Native American, Archaeological, and Historic Preservation Statutes	6.6

6.10 Environmental Justice	6.6
6.11 Recreational Fisheries	6.6
6.12 Chemical and Material Storage	6.7
6.13 Waste Management	6.7
6.14 Emergency Planning and Community Right-to-Know	6.8
6.15 Pollution Prevention	6.8
6.16 Radioactive Air Emissions	6.8
6.17 Nonradioactive Air Emissions	6.9
6.18 Liquid Discharges to the Ground or Publicly Owned Treatment Works	6.9
6.19 Special Requirements for Targets Supplied to DOE by a Private Vendor	6.9
6.20 Environmental Review and Consultation	6.10
7.0 Glossary of Terms	7.1
8.0 List of Preparers and Contributors	8.1
9.0 Bibliography	9.1
Appendix A - Molybdenum-99 Production and Separation Performance Characteristics	A.1
Appendix B - Analysis of Transportation Impacts	B.1
Appendix C - Input to GENII Calculations for all Alternatives	C.1
Appendix D - Climate and Meteorology	D.1

Figures

S-1	Molybdenum-99 Production Process	ix
3-1	Molybdenum-99 Production Process	3.3
3-2	Location of Los Alamos National Laboratory and Sandia National Laboratories	3.9
3-3	Sandia National Laboratories/Los Alamos National Laboratory Isotope Production Process ..	3.11
3-4	Configuration of the Completed Target	3.12
3-5	Uranium Target Fabrication Line, Process Flow and Procedures	3.13
3-6	Annular Core Research Reactor Floor Plan	3.15
3-7	SNL/NM Technical Area V Complex	3.17
3-8	Current Hot Cell Configuration	3.18
3-9	Hot Cell Area Configuration for Full Isotope Production	3.19
3-10	Core Cooling System for the Omega West Reactor	3.28
3-11	Cutaway Illustration of the Omega West Reactor	3.30
3-12	Target Stringer Assembly	3.32
3-13	Molybdenum-99 Hot Cell Processing	3.34
3-14	Relative Locations of the Bulk Shielding Reactor, Oak Ridge Research Reactor, and the Radioisotope Development Laboratory Hot Cells	3.40
3-15	Layout of the Three Floor Levels of the Radioisotope Development Laboratory	3.41
4-1	Location of Albuquerque, New Mexico, and Surrounding Areas	4.2
4-2	Location of Technical Areas Within KAFB and Sandia National Laboratories	4.4
4-3	Location of the Albuquerque-Belen Basin	4.8
4-4	Fault Zones Near Sandia National Laboratories/New Mexico	4.9
4-5	Major Transportation Services Near Sandia National Laboratories/New Mexico	4.14
4-6	Local Transportation Routes Near Sandia National Laboratories/New Mexico	4.15
4-7	Regional Map of Los Alamos National Laboratory and Surrounding Area	4.22
4-8	Technical Areas of Los Alamos National Laboratory	4.23
4-9	Land Use for Los Alamos National Laboratory and Surrounding Area	4.27
4-10	Stratigraphy of the Pajarito Plateau	4.28
4-11	Fault Zones Surrounding Los Alamos National Laboratory	4.29
4-12	Plant Communities on the Pajarito Plateau	4.36
4-13	Floodplain Map of Los Alamos National Laboratory	4.37
4-14	Regional Transportation Routes Near Los Alamos National Laboratory	4.42
4-15	Local Transportation Routes Near Los Alamos National Laboratory	4.43
4-16	Location of Oak Ridge National Laboratory	4.47
4-17	Land Use for the Oak Ridge Reservation	4.48
4-18	Oak Ridge National Laboratory and Surrounding Area	4.50
4-19	Regional Geologic Map of the Oak Ridge Reservation	4.54
4-20	Plant Communities on the Oak Ridge Reservation	4.59
4-21	Highway System for the Oak Ridge Reservation	4.63
4-22	Location of Idaho National Engineering Laboratory	4.68
4-23	Selected Land Uses for the Idaho National Engineering Laboratory Region	4.70

4-24	Region of Influence for Idaho National Engineering Laboratory	4.72
4-25	Geology of the Eastern Snake River Plain	4.75
4-26	Rift Zones and Volcanic Structures Near the Idaho National Engineering Laboratory	4.77
4-27	Major Volcanic and Tectonic Elements Near the Idaho National Engineering Laboratory	4.78
5-1	Waste Generation and Management	5.34
5-2	Minority Population - Annular Core Research Reactor	5.82
5-3	Low-Income Population - Annular Core Research Reactor	5.83
5-4	Minority Population - Omega West	5.87
5-5	Low-Income Population - Omega West	5.88
5-6	Minority Population - Oak Ridge Research Reactor	5.91
5-7	Low-Income Population - Oak Ridge Research Reactor	5.92
5-8	Minority Population - Power Burst Facility	5.95
5-9	Low-Income Population - Power Burst Facility	5.96
D-1	Average Distribution of Wind Directions and Wind Speeds at Albuquerque International Airport	D.3
D-2	Average Distribution of Wind Directions and Wind Speeds at Los Alamos National Laboratory (G Area)	D.6
D-3	Average Distribution of Wind Directions and Wind Speeds at Los Alamos National Laboratory (Technical Area-50 monitoring site)	D.7
D-4	Average Distribution of Wind Directions and Wind Speeds at Oak Ridge National Laboratory	D.9
D.5	Average Distribution of Wind Directions and Wind Speeds at Idaho National Engineering Laboratory (Central Facilities Area)	D.12
D.6	Average Distribution of Wind Directions and Wind Speeds at Idaho National Engineering Laboratory (Technical Area North)	D.13

Tables

S-1	Alternatives Considered, But Dismissed	xi
S-2	Summary of Environmental Consequences and Comparison of Alternatives at 100% Production	xiii
3-1	Summary of Environmental Consequences and Comparison of Alternatives	3.61
3-2	Comparison of Alternatives for Mo-99 Production at 100% Production	3.65
4-1	Employment by Major Industry for Bernalillo County	4.6
4-2	Comparison of Air Quality Standards and Maximum Concentrations at Sandia National Laboratories	4.11
4-3	Estimated Public Radiation Exposure from SNL/NM Activities	4.16
4-4	Radiation Doses Received by Personnel Working at the Annular Core Research Reactor/Hot Cell Facility Area During 1993 and 1994	4.17
4-5	Existing SNL/NM Utility Resource Requirements	4.18
4-6	Existing SNL/NM Chemical Resource Requirements	4.18
4-7	Regional Employment Profile	4.26
4-8	Nonradiological Ambient Air Monitoring Results in the Region of Los Alamos National Laboratory	4.31
4-9	Selected Radionuclide Concentrations in the Air from and Around the Los Alamos National Laboratory	4.33
4-10	Threatened, Endangered, and Candidate Species Potentially Present at Los Alamos National Laboratory	4.39
4-11	Existing Los Alamos National Laboratory Utility Resource Requirements	4.44
4-12	Existing Los Alamos National Laboratory Chemical Resource Requirements	4.44
4-13	Employment by Industry for the Oak Ridge Region of Influence, by County, and for the State of Tennessee, 1990 and 1993	4.52
4-14	1992 Radionuclide Concentrations in the Air Around Oak Ridge National Laboratory	4.57
4-15	Federal- and State-Listed Threatened, Endangered, and Other Special-Status Species That Potentially Occur on or in the Vicinity of the Oak Ridge Reservation	4.61
4-16	Summary of Effective Dose Equivalents to the Maximally Exposed Individual from Oak Ridge Reservation Operations During 1992	4.64
4-17	Summary of Collective Effective Dose Equivalents to the Public from Oak Ridge Reservation Operations During 1992	4.64
4-18	Existing Oak Ridge Reservation Utility Resource Requirements	4.65
4-19	Existing Oak Ridge Reservation Chemical Resource Requirements	4.66
4-20	1993 Employment Profile in the Idaho National Engineering Laboratory Region of Influence	4.73
4-21	Summary of Radioactive Emissions to the Atmosphere from the Power Burst Facility and the Idaho National Engineering Laboratory Site	4.80
4-22	Gross Alpha Activity in Air Around Idaho National Engineering Laboratory	4.80
4-23	Gross Beta Activity in Air Around Idaho National Engineering Laboratory	4.81

4-24	Threatened and Endangered Species, Special Species of Concern, and Sensitive Species That May Be Found on the Idaho National Engineering Laboratory	4.84
4-25	Baseline Traffic for Selected Highway Segments on the Idaho National Engineering Laboratory	4.85
4-26	Baseline Annual Vehicle Miles Traveled for Idaho National Engineering Laboratory-Related Traffic	4.86
4-27	Maximum Individual Effective Dose Equivalent from 1993 Idaho National Engineering Laboratory Emissions to the Air	4.87
4-28	Existing Idaho National Engineering Laboratory Utility Resource Requirements	4.89
4-29	Existing Idaho National Engineering Laboratory Fuel Resource Requirements	4.90
5-1	Cost and Labor Estimates for Facility Modification and Operation of the Various Alternatives	5.4
5-2	Estimated Annual Air Emissions from the Annular Core Research Reactor During Target Irradiation	5.8
5-3	Annual Radiological Dose and Consequences from Routine Air Emissions from the Annular Core Research Reactor During Target Irradiation and Post-Irradiation Processing in the Hot Cell Facility	5.9
5-4	Estimated Annual Radionuclide Emissions from Hot Cell Facilities During Processing of Irradiated Targets for Molybdenum-99 Extraction	5.10
5-5	Annual Radiological Dose and Consequences from Routine Air Emissions from the Omega West Reactor During Target Irradiation and Post-Irradiation Processing at the Chemistry and Metallurgy Research Facility	5.10
5-6	Annual Radiological Dose and Consequences from Routine Air Emissions from the Oak Ridge Research Reactor During Target Irradiation and Post-Irradiation Processing in ORNL's Hot Cell Facility	5.11
5-7	Estimated Annual Air Emissions from the Power Burst Facility During Target Irradiation	5.12
5-8	Annual Radiological Dose and Consequences from Routine Air Emissions from the Power Burst Facility During Target Irradiation and Post-Irradiation Processing in the Hot Cell Facility	5.12
5-9	Summary of Transportation Routing Information	5.17
5-10	Radiological Impacts Due to Routine or Incident-Free Transportation	5.19
5-11	Nonradiological Impacts to the Public Due to Routine or Incident-Free Transportation	5.20
5-12	Radiological Risks Due to Transportation Accidents, Including Truck and Air Transport	5.21
5-13	Accidental Releases and Dose to the Maximally Exposed Individual Located 100 m from Transport Accident	5.22
5-14	Nonradiological Impacts Due to Truck Transportation Accidents	5.23
5-15	Routine Radiological Exposures to Workers During Facility Operations	5.24
5-16	Estimated Annual Quantities of Selected Resources Required for 100% Operation and Upgrade of Facilities at Each Site	5.27
5-17	Approximate Yearly Chemical Usage for Production of Molybdenum-99 at Any of the Proposed Project Sites	5.27
5-18	Waste Characterization Data Summary	5.33
5-19	Summary of Site Waste Management Cumulative Impacts	5.39

5-20	Radionuclides Released from Annular Core Research Reactor During a Postulated Four Fuel Element Rupture Scenario	5.45
5-21	Dose and Consequences for the Four Fuel Element Rupture Accident at the Annular Core Research Reactor	5.46
5-22	Radionuclides Released from the Annular Core Research Reactor During a Postulated Target Rupture Scenario	5.47
5-23	Dose and Consequences for the Target Rupture Accident at the Annular Core Research Reactor	5.48
5-24	Radionuclides Released to the Atmosphere During a Postulated Target Rupture Scenario During Transfer	5.49
5-25	Dose and Consequences for Release from a Single Target Rupture at SNL/NM During Target Transfer Following Target Irradiation	5.49
5-26	Estimated Releases from the Hot Cell Facility Accident During Mo-99 Target Processing	5.50
5-27	Dose and Consequences for an Accidental Release from the Hot Cell Facility at SNL/NM During Mo-99 Target Processing	5.51
5-28	Dose and Consequences for an Accidental Release from the SNL/NM Hot Cell Facility During Iodine-125 Target Processing	5.52
5-29	Radionuclides Released from the Omega West Reactor During a Postulated Fuel Melt Scenario	5.53
5-30	Dose and Consequences for an Accidental Fuel Melt Release from the Omega West Reactor	5.53
5-31	Dose and Consequences for an Accidental Target Rupture from the Omega West Reactor	5.54
5-32	Estimated Dose to an Individual Hiker from a Coolant Leak at the LANL Omega West Reactor	5.55
5-33	Dose and Consequences for an Accidental Release During Mo-99 Target Transfer at the Omega West Reactor	5.57
5-34	Dose and Consequences for an Accidental Release from the Chemistry and Metallurgy Research Facility Hot Cells from Processing Mo-99 Targets	5.58
5-35	Dose and Consequences for an Accidental Release from the Chemistry and Metallurgy Research Facility Hot Cells from Processing of Iodine-125 Targets	5.58
5-36	Dose and Consequences for an Accidental Fuel Melt Release from the Oak Ridge Research Reactor	5.59
5-37	Dose and Consequences for the Target Rupture Accident at Oak Ridge Research Reactor	5.60
5-38	Dose and Consequences for an Accidental Release from Target Rupture at Oak Ridge National Laboratory During Mo-99 Target Transfer	5.61
5-39	Dose and Consequences for the Accidental Release of Noble Gases from Mo-99 Target Processing at the ORNL Hot Cell Facility	5.62
5-40	Dose and Consequences for the Accidental Release of Noble Gases from Iodine-125 Target Processing at the ORNL Hot Cell Facility	5.63
5-41	Dose and Consequences for the Fuel Melt Accident at Power Burst Facility	5.64
5-42	Dose and Consequences for the Target Rupture Accident at the Power Burst Facility	5.65
5-43	Dose and Consequences for the Accidental Release from Target Rupture at INEL Power Burst Facility During Mo-99 Target Transfer	5.66

5-44	Dose and Consequences for the Accidental Release of Noble Gases from INEL Hot Cells During Mo-99 Target Processing	5.67
5-45	Dose and Consequences for the Accidental Release of Noble Gases from INEL Hot Cells During Iodine-125 Target Processing	5.68
5-46	Operational Injuries, Illnesses, and Fatalities for Facility Construction and Operation	5.69
5-47	Resources Required to Prepare and Operate DOE Facilities for Production of Medical Radioisotopes	5.79
5-48	Location of Minority and Low-Income Populations Surrounding the Annular Core Research Reactor by Distance and Direction	5.84
5-49	Location of Minority and Low-Income Populations by Distance and Direction from Omega West Reactor	5.89
5-50	Location of Minority and Low-Income Populations Surrounding the Oak Ridge Research Reactor by Distance and Direction	5.93
5-51	Location of Minority and Low-Income Populations Surrounding Power Burst Facility by Distance and Direction	5.97
5-52	Comparison of Estimated Project Costs at Candidate Sites	5.100
B-1	Transport Scenarios Based on Handling or Operation Location	B.2
B-2	Summary of Transportation Routing Information	B.6
B-3	RADTRAN Input Parameters for Truck Shipments	B.11
B-4	RADTRAN 4 Input Parameters for Passenger Air Shipments	B.14
B-5	RADTRAN Accident Impact Parameters for Air Shipments	B.16
B-6	Radiological Inventories by Material Type Used in Analyses	B.17
B-7	Radiological Impacts Due to Routine or Incident-free Transportation	B.19
B-8	Nonradiological Impacts to the Public Due to Routine or Incident-Free Transportation	B.21
B-9	Accident Severity Categories and Conditional Probabilities	B.23
B-10	Release Fractions Used for Assessment of Accident Impacts	B.23
B-11	Radiological Risk Due to Transportation Accidents, Including Truck and Air Transport	B.24
B-12	Accidental Releases and Dose to the Maximally Exposed Individual Located 100 m from Transport Accident	B.25
B-13	Nonradiological Impacts Due to Truck Transportation Accidents	B.26
B-14	Routine Transportation Impacts for Shipments of 100% of the US Demand to Nordion in Ottawa, Canada	B.27
B-15	Transportation Accident Impacts for Shipments of 100% of the US Demand to Nordion in Ottawa, Canada	B.27
B-16	Routine Transportation Impacts for Shipments of 100% of the U.S. Demand to U.S. Distributors	B.28
B-17	Transportation Accident Impacts for Shipments of 100% of the U.S. Demand to U.S. Distributors	B.29
C-1	Site-Specific Parameters Used in Radiologic Calculations	C.2
C-2	Sandia National Laboratories/New Mexico Population Grid Based on 1990 Census Data Total = 606718	C.5
C-3	Los Alamos National Laboratory TA-2 Omega West Reactor 1993 Projection Based on 1990 Data Total = 236825	C.6

C-4	Los Alamos National Laboratory TA-3 Chemistry and Metallurgy Research Facility Total = 250889	C.7
C-5	Oak Ridge National Laboratory 1992 Projected Population Based on 1990 Census Data Total = 905740	C.8
C-6	Idaho National Engineering Laboratory Power Burst Facility Population Grid Based on 1993 Annual Report Total = 121455	C.9
C-7	Sandia National Laboratories/New Mexico 15 m Albuquerque International Airport	C.12
C-8	Chemistry and Metallurgy Research Facility and Omega West Reactor Stack Releases	C.15
C-9	Omega West Reactor Ground Level Releases	C.18
C-10	Oak Ridge Research Reactor - X10 Facility	C.21
C-11	Idaho National Engineering Laboratory, Near the Power Burst Facility	C.24
C-12	Food Production Grid for SNL/NM, TA-V (Annular Core Research Reactor)	C.27
C-13	Food Production Grid for SNL/NM, TA-V (Annular Core Research Reactor)	C.28
C-14	Food Production Grid for LANL, Centered on TA-53 (Beef Cattle)	C.29
C-15	Food Production Grid for LANL, Centered on TA-53 (Dairy Cattle)	C.30
C-16	INEL PBF Food Production Grid (Beef Cattle)	C.31
C-17	INEL PBF Food Production Grid (Dairy Cattle)	C.32
D-1	Sandia National Laboratorie/New Mexico Average Local Climatology	D.2
D-2	Los Alamos National Laboratory Average Local Climatology	D.4
D-3	Oak Ridge National Laboratory Average Local Climatology	D.8
D-4	Idaho National Engineering Laboratory Average Local Climatology	D.10

Acronyms and Abbreviations

ac	acre
ACRR	Annular Core Research Reactor (SNL/NM)
AECL	Atomic Energy of Canada Ltd.
AFRRI	Armed Forces Radiobiology Research Institute
AGS	Alternating Gradient Synchrotron
AIA	Albuquerque International Airport
AL	Alabama
ALARA	as low as reasonably achievable
ANC	Aerojet Nuclear Company
ANL	Argonne National Laboratory
ANMS	Advanced Nuclear and Medical Systems
ANL-W	Argonne National Laboratory-West
ANSI	American National Standards Institute
AQCR	Air Quality Control Region
AR	Arkansas
ARA	Auxiliary Reactor Area
BLIP	Brookhaven LINAC Isotope Producer
BLM	Bureau of Land Management
BNCT	Boron Neutron Capture Therapy
BNL	Brookhaven National Laboratory
BSR	Bulk Shielding Reactor (ORNL)
CAA	Clean Air Act
CAP-88	Clean Air Act Assessment Package-1988
CEQ	Council on Environmental Quality
CFA	Central Facilities Area
cfm	cubic feet per minute
CFR	Code of Federal Regulations
Ci	curies
cm	centimeter
CMR	Chemistry and Metallurgy Research (LANL)
CNEL	Community Noise Equivalent Level
COE	U.S. Army Corps of Engineers
D&D	decontamination and decommissioning
dB	decibel
dB(A)	A-weighted decibel
DCG	Derived Concentration Guide
DMF	Drug Master File
DOC	U.S. Department of Commerce
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy

DOI	U.S. Department of Interior
DOT	U.S. Department of Transportation
EA	Environmental Assessment
EBR-1	Experimental Breeder Reactor-1
EDE	Effective Dose Equivalent
EPA	U.S. Environmental Protection Agency
FDA	Food and Drug Administration
FDP	Flourinel Dissolution Process
FEIS	final environmental impact statement
FFTF	Fast Flux Test Facility
FONSI	Finding of No Significant Impact
FR	federal register
FREC	fuel-ringed external cavities
ft	foot/feet
FTE	full-time equivalent
FWHM	full width at half maximum
g	gram/grams
GA	Georgia
gal	gallon/gallons
GB	glovebox
GeV	giga (billion) electron volts
GIF	Gamma Irradiation Facility
GOCO	government-owned contractor-operated
h	hour
ha	hectare
³ H	tritium
HCF	Hot Cell Facility
HEPA	high efficiency particulate air
HEU	highly enriched uranium
HFR	High Flux Reactor
I	iodine
IBTC	Idaho Brain Tumor Center
ICRP	International Commission on Radiological Protection
ICPP	Idaho Chemical Processing Plant
IDHW	Idaho Department of Health and Welfare
IFSF	Irradiated Fuel Storage Facility
IL	Illinois
in.	inch/inches
INEL	Idaho National Engineering Laboratory
IPC	Idaho Power Company
IRE	Institute National des Radio-elements

I	KAFB	Kirtland Air Force Base
	kg	kilogram
	km	kilometer/kilometers
	km ²	square kilometers
	kmph	kilometers per hour
	kV	kilovolt
	kW	kilowatt
	KY	Kentucky
	L	liter
	LAMPF	Los Alamos Meson Physics Facility
	LANL	Los Alamos National Laboratory
	LATA	Los Alamos Technical Associates
	LCF	latent cancer fatality
	Ldn	day-night sound level
	Leq	equivalent sound level
	LEU	low-enriched uranium
	LINAC	linear accelerator
	LLNL	Lawrence Livermore National Laboratory
	LLW	low-level waste
	m	meter/meters
	m ²	square meters
	m ³	cubic meters
	Ma	million years
	mA	milliamperes
	mCi	millicuries
	MED	Manhattan Engineering District
	MEI	maximally exposed individual
	MESODIF	mesoscale diffusion (meteorological technique)
	MeV	million electron volts
	mi	mile/miles
	mi ²	square miles
	min	minute/minutes
	MIPP	Medical Isotope Production Project
	MIPR	Medical Isotope Production Reactor
	MIPC	Medical Isotope Production Center
	ml	milliliter
	mm	millimeter
	MMES	Martin Marietta Energy Systems
	MMI	Modified Mercalli Intensity
	Mo	molybdenum
	MO	Missouri
	mph	miles per hour
	mR	milliroentgen
	mrem	millirem

MS	Mississippi
MSA	Metropolitan Statistical Area
mSv	millisieverts
MV	megavolt
MVa	megavolts-amperes
mW	milliwatts
MW	megawatt
MWh	megawatt hour
MWt	megawatt thermal
nCi	nanocuries
NC	North Carolina
NCRP	National Council of Radiation Protection
NDT	non-destructive testing
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
NMAC	New Mexico Air Code
NMDGF	New Mexico Department of Game and Fish
NOAA	National Oceanographic and Atmospheric Administration
NOI	notice of intent
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
NRF	Naval Reactors Facility
NRU	National Research Universal (reactor)
NTS	Nevada Test Site
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
ORRR	Oak Ridge Research Reactor (ORNL)
OSHA	Occupational Safety and Health Administration
OWR	Omega West Reactor (LANL)
PAM	perimeter air monitor
person-rem	unit collective population dose
PBF	Power Burst Facility (INEL)
PEIS	Programmatic Environmental Impact Statement
RAL	Remote Analytic Laboratory (ORNL)
RAM	regional air monitor
RCRA	Resource Conservation and Recovery Act
RDL	Radioisotope Development Laboratory (ORR)
REIS	Regional Economic Information System
RERTR	Reduced Enrichment for Research and Test Reactors
RIMS	Regional Input-Output Modeling System
ROD	Record of Decision

ROI	region of influence
RWMC	Radioactive Waste Management Complex (INEL)
SAR	Safety Analysis Report
SC	South Carolina
SNL/NM	Sandia National Laboratories/New Mexico
SNF PEIS	Spent Nuclear Fuel Programmatic Environmental Impact Statement
SPR	Sandia Pulsed Reactor
SPERT	Special Power Excursion Reactor Test
SPUR	Sandia Pulse Reactor
SRS	Savannah River Site
Sv	sievert
TA	technical area (LANL only)
TAN	Test Area North (INEL)
Tc	technetium
TEDE	total effective dose equivalent
TFBA	Thermal Fuels Behavior Program
TI	Transportation Index
TLD	Thermoluminescent Dosimetry
TN	Tennessee
TRA	Test Reactor Area (INEL)
TRIGA	Training, Research, Isotope Production, General Atomics (reactor)
TSP	total suspended particulates
TSR	technical safety requirements
TVA	Tennessee Valley Authority
TVV	Thermo Technology Ventures
U	uranium
UBC	Uniform Building Code
USAF	U.S. Air Force
USC	United States Code
USDA-SCS	U.S. Department of Agriculture, Soil Conservation Service
USFWS	U.S. Fish and Wildlife Service
VA	Virginia
WERF	Waste Experimental Reduction Facility (INEL)
WIPP	Waste Isolation Pilot Plant
wk	week
yr	year
yd	yard/yards
yd ²	square yards
yd ³	cubic yards

Units of Measure

The principal units of measurement used in this EIS are SI units, an abbreviation for *Système Internationale d'Unités*, a metric system, accepted by the International Organization of Standardization as the legal standard at a meeting in Elsinore, Denmark, in 1966. In this system, most units are made up of combinations of six basic units, of which length in meters, mass in kilograms, and time in seconds are of importance in this EIS.

In this EIS, values given in SI units are followed by values shown as common units in parentheses.

Units of Measure

Symbol	Name	Symbol	Name
Temperature:		Length:	
°C	degrees Centigrade	cm	centimeter (1 x 10 ⁻² m)
°F	degrees Fahrenheit	ft	foot
Time:		in.	inch
		km	kilometer (1 x 10 ³ m)
d	day	m	meter
h	hour	mi	mile
wk	week	mm	millimeter (1 x 10 ⁻³ m)
yr	year	µm	micrometer (1 x 10 ⁻⁶ m)
Rate:		Area:	
kmph	kilometers per hour	ac	acre
mph	miles per hour	ft ²	square foot
ft ³ /h	cubic feet per hour	km ²	square kilometer
		mi ²	square mile
Volume:		Energy:	
cm ³	cubic centimeter	kV	kilovolt
ft ³	cubic feet	kW	kilowatt
gal	gallon	MeV	million electron volts
L	liter	MV	megavolt
m ³	cubic meter	MW	megawatt
ppm	parts per million	MWt	megawatt thermal
yd ³	cubic yard	Rate:	
Sound:		gpm	gallons per minute
dB(A)	A-weighted decibel		
Ldn	day-night sound level		
Leq	equivalent sound level		

Nomenclature

Units of Radioactivity

Radioactivity	
Symbol	Name
Ci	curie
mCi	millicurie (1×10^{-3} Ci)
μ Ci	microcurie (1×10^{-6} Ci)
nCi	nanocurie (1×10^{-9} Ci)
pCi	picocurie (1×10^{-12} Ci)
aCi	attocurie (1×10^{-18} Ci)
Bq	becquerel

Units of Radiation Dose

Radiation Dose	
Symbol	Name
mrad	millirad (1×10^{-3} rad)
mrem	millirem (1×10^{-3} rem)
Sv	sievert
μ Sv	microsievert (1×10^{-6} Sv)
R	roentgen
mR	milliroentgen (1×10^{-3} R)
μ R	microroentgen (1×10^{-6} R)
1 Sv	100 rem

Numerical (Scientific or Exponential) Notation

Numbers that are very small or very large are often expressed in scientific or exponential notation as a matter of convenience. For example, the number 0.000034 may be expressed as 3.4×10^{-5} or 3.4E-05 and 65,000 may be expressed as 6.5×10^4 or 6.5E+04. Multiples or submultiples of the basic units are also used. A partial list of multiples and submultiples follows:

Name	Symbol		Value Multiplied by:
atto	a	0.0000000000000001	or 1×10^{-18} or 1E-18
pico	p	0.000000000001	or 1×10^{-12} or 1E-12
nano	n	0.000000001	or 1×10^{-9} or 1E-09
micro	μ	0.000001	or 1×10^{-6} or 1E-06
milli	m	0.001	or 1×10^{-3} or 1E-03
kilo	k	1,000	or 1×10^3 or 1E+03
mega	M	1,000,000	or 1×10^6 or 1E+06
giga	G	1,000,000,000	or 1×10^9 or 1E+09
tera	T	1,000,000,000,000	or 1×10^{12} or 1E+12

The following symbols are occasionally used in conjunction with numerical expressions:

$<$ less than

$\leq$ less than or equal to

$>$ greater than

$\geq$ greater than or equal to

In this EIS, numerical values that are less than 0.001 or greater than 9999 are generally expressed in exponential notation.

Conversion Table

Base Unit	Multiply By	To Obtain	Base Unit	Multiply By	To Obtain
in.	2.54	cm	cm	0.394	in.
ft	0.305	m	m	3.28	ft
mi	1.61	km	km	0.621	mi
lb	0.454	kg	kg	2.205	lb
gal	3.785	L	L	0.264	gal
ft ²	0.093	m ²	m ²	10.76	ft ²
mi ²	2.59	km ²	km ²	0.386	mi ²
ft ³	0.028	m ³	m ³	35.3	ft ³
nCi	1000	pCi	pCi	0.001	nCi
pCi/L	10 ⁻⁹	μCi/mL	μCi/mL	10 ⁹	pCi/L
pCi/m ³	10 ⁻¹²	Ci/m ³	Ci/m ³	10 ¹²	pCi/m ³
pCi/m ³	10 ⁻¹⁵	mCi/cm ³	mCi/cm ³	10 ¹⁵	pCi/m ³
mCi/km ²	1.0	nCi/m ²	nCi/m ²	1.0	mCi/km ²
becquerel	2.7 x 10 ⁻¹¹	curie	curie	3.7 x 10 ¹⁰	becquerel
gray	100	rad	rad	0.01	gray
sievert	100	rem	rem	0.01	sievert
ppb	0.001	ppm	ppm	1000	ppb
°F	(°F - 32) ÷ 9/5	°C	°C	(°C x 9/5) + 32	°F
g	0.035	oz	oz	28.349	g

Element and Chemical Nomenclature

Symbol	Constituent
Ba	barium
CO	carbon monoxide
H	hydrogen
I	iodine
Mo	molybdenum
Na	sodium
NO ₂	nitrogen dioxide
O	oxygen
SO ₂	sulfur dioxide
Tc	technetium
U	uranium
Xe	xenon

Radionuclide Nomenclature ^(a,b)

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
Am-241	americium-241	432 yr	Pr-144m	praseodymium-144m	7.2 min
Ar-41	argon-41	1.8 h	Pu-238	plutonium-238	87.7 yr
Ba-137m	barium-137m	2.6 min	Pu-239	plutonium-239	2.4 x 10 ⁴ yr
Ba-140	barium-140	12.75 d	Pu-240	plutonium-240	6.5 x 10 ³ yr
Br-83	bromine-83	2.4 h	Rh-103m	rhodium-103m	56.12 min
Ce-141	cerium-141	32.5 d	Rh-106	rhodium-106	29.9 sec
Ce-144	cerium-144	284 d	Ru-103	ruthenium-103	39.3 d
Cs-137	cesium-137	30 yr	Ru-106	ruthenium-106	368 d
H-3	tritium	12.3 yr	Sm-147	samarium-147	1.06 x 10 ¹¹ yr
I-125	iodine-125	59.4 d	Sr-89	strontium-89	50.5 d
I-129	iodine-129	1.6 x 10 ⁷ yr	Sr-90	strontium-90	29.1 yr
I-131	iodine-131	8 d	Tc-99	technetium-99	2.1 x 10 ⁵ yr
I-132	iodine-132	2.28 h	Tc-99m	metastable technetium-99	6.0 h
I-133	iodine-133	20.8 h	Te-127	tellurium-127	9.4 h
I-134	iodine-134	52.6 min	Te-127m	tellurium-127m	109 d
I-135	iodine-135	6.57 h	Te-129	tellurium-129	1.16 h
Kr-83m	krypton-83m	1.86 h	Te-129m	tellurium-129m	33.6 d
Kr-85	krypton-85	10.7 yr	Te-132	tellurium-132	3.26 d
Kr-85m	krypton-85m	4.48 h	U-234	uranium-234	2.4 x 10 ⁵ yr
Kr-87	krypton-87	1.27 h	U-235	uranium-235	7 x 10 ⁸ yr
Kr-88	krypton-88	2.84 h	Xe-125	xenon-125	17.1 h
La-140	lanthanum-140	1.678 d	Xe-131m	xenon-131m	11.9 d
Mo-99	molybdenum-99	2.747 d	Xe-133	xenon-133	5.2 d
Nb-95	niobium-95	35 d	Xe-133m	xenon-133m	2.19 d
Nb-95m	niobium-95m	3.61 d	Xe-135	xenon-135	9.1 h
Nd-147	neodymium-147	10.98 d	Xe-135m	xenon-135m	15.3 min
Pm-147	promethium-147	2.6 y	Xe-138	xenon-138	14.1 min
Pr-143	praseodymium-143	13.57 d	Y-90	yttrium-90	2.67 d
Pr-144	praseodymium-144	17.28 min	Y-91	yttrium-91	58.5 d

(a) From *CRC Handbook of Chemistry and Physics*. 74th edition. ed. David R. Lide, CRC Press, Boca Raton, Florida 1993.

(b) Isomers are indicated by the addition of an *m*.

1.0 Introduction

The U.S. Department of Energy (DOE) proposes to establish a domestic source for and to produce molybdenum-99 (Mo-99) and related medical isotopes, including iodine-131, xenon-133, and iodine-125. DOE proposed this project to ensure a reliable supply to the U.S. medical community of the metastable isotope technetium-99 (Tc-99m), which is produced from Mo-99. This Final Environmental Impact Statement (EIS) analyzes the environmental impacts of alternatives to accomplish the proposed action.

On February 7, 1995, DOE issued an environmental assessment (EA) for public comment on the proposed action to produce Mo-99 and related medical isotopes using the Chemistry and Metallurgy Research Facility at Los Alamos National Laboratory (LANL) and the Annular Core Research Reactor at Sandia National Laboratories/New Mexico (SNL/NM). The public review and comment period on the EA ended on May 1, 1995. Based on the EA and comments received, DOE decided to prepare a Draft EIS.

1.1 Organization

- **Section 1 - Introduction:** Medical Isotopes Production Project (MIPP) background and the environmental analysis process.
- **Section 2 - Purpose of and Need for Action:** reasons why DOE needs to take action at this time.
- **Section 3 - Alternatives:** includes a summary and comparison of expected environmental impacts for each alternative.
- **Section 4 - Affected Environment:** aspects of the human and physical environment that might be affected.
- **Section 5 - Environmental Consequences:** analysis of the impacts on the affected human and physical elements of the environment.
- **Section 6 - Regulatory Framework:** environmental regulations that could apply to the proposed project.
- **Section 7 - Glossary of Terms:** terms used in this EIS are defined.
- **Section 8 - List of Preparers and Contributors:** persons who contributed to the preparation of this EIS.

- **Section 9 - Bibliography:** all documents used in the preparation of this EIS. Each of those listed is publicly available.
- **Appendix A - Molybdenum-99:** discussion of the Mo-99 production process.
- **Appendix B - Analysis of Transportation Impacts:** detailed description of the impacts of transportation of medical isotopes and associated wastes.
- **Appendix C - Input to the GENII Calculations for All Alternatives:** description of the various input data for wind, population, and food production for each site.
- **Appendix D - Climatology and Meteorology:** description of characteristics of climate for each of the proposed sites.

1.2 Alternatives Analyzed

This EIS evaluates the reasonable alternatives that would meet the purpose and need for agency action and identifies alternatives that were considered but eliminated from detailed study, and briefly discusses the reasons for their elimination. In addition, a No Action alternative, as required by the Council on Environmental Quality regulations for compliance with the National Environmental Policy Act (NEPA), is presented as a basis for comparison.

Alternatives evaluated in detail are

- **No Action** - Under this alternative, DOE would not establish a production source for Mo-99.
- **Annular Core Research Reactor - Sandia National Laboratories/New Mexico (SNL/NM), Albuquerque, New Mexico (DOE's preferred alternative) and the Chemistry and Metallurgy Research Facility - Los Alamos National Laboratory, Los Alamos, New Mexico.** Wing 9 of the Los Alamos National Laboratory (LANL) Chemistry and Metallurgy Research building or a building within an existing facility at SNL/NM would be used to fabricate targets. The operating Annular Core Research Reactor and supporting facilities at SNL/NM would be used to produce Mo-99 and related isotopes. Low-level radioactive wastes would be disposed of at the Nevada Test Site.
- **Omega West Reactor/Chemistry and Metallurgy Research Facility - Los Alamos National Laboratory (LANL), Los Alamos, New Mexico.** All process steps would be carried out onsite at LANL. Wing 9 of the Chemistry and Metallurgy Research building would be used for fabricating the targets and recovering Mo-99 in the hot cells. The target irradiation would occur in the Omega West Reactor, which would be repaired and restarted for this purpose. Low-level radioactive wastes would be disposed of onsite at LANL.

- **Oak Ridge Research Reactor/Radioisotope Development Laboratory - Oak Ridge National Laboratory (ORNL)**, Oak Ridge, Tennessee. The Radioisotope Development Laboratory would be customized and dedicated for target fabrication and Mo-99 processing. Mo-99 would be produced by irradiating targets using the Oak Ridge Research Reactor, which would be restarted and redesignated as the Medical Isotope Production Center. Low-level radioactive wastes would be disposed of at the Nevada Test Site.
- **Power Burst Facility/Test Area North - Idaho National Engineering Laboratory (INEL)**, Idaho Falls, Idaho. All process steps would be carried out onsite at INEL. Targets would be fabricated at INEL at the Test Area North in a building similar to the Experimental Test Reactor Critical Facility annex or the lower floor of the Materials Test Reactor building. The targets would be shipped for irradiation to the Power Burst Facility, which would be restarted for this purpose. The Mo-99 would be extracted from the irradiated targets, either in existing hot cells at the Test Area North or at new hot cells constructed for this purpose. Low-level radioactive wastes would be disposed of onsite at INEL.

1.3 Laws and Regulations

This EIS was prepared pursuant to the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321 et seq.), the President's Council on Environmental Quality NEPA regulations (40 CFR Parts 1500-1508), and the DOE NEPA regulations (10 CFR Part 1021).

1.4 Public Participation, Outreach, and Changes from the Draft EIS

1.4.1 Public Participation and Outreach

The Department of Energy has provided multiple opportunities for public involvement in the EIS development and review process for the proposed Medical Isotopes Production Project. The decision to prepare an EIS for the proposed project was in part based on public comments received on an earlier environmental assessment. The environmental assessment was prepared to analyze the potential impacts of a proposal to produce medical isotopes using facilities at Los Alamos National Laboratory and at Sandia National Laboratories/New Mexico. The DOE initiated this EIS with the desire of assuring stakeholders and interested parties of the limited environmental impacts of the proposed project.

On July 6, 1995, DOE issued a notice of intent in the *Federal Register* (60 FR 35191-35195) which announced that DOE would prepare an EIS for the proposed Medical Isotopes Production Project. The notice of intent also provided the schedule for the public scoping meetings for the EIS. Additional public notice of the proposed project and the schedule for the public scoping meetings was provided through the placement of advertisements in local newspapers in the communities with alternative facilities under consideration. Local public notices were placed in the following newspapers.

New Mexico:	Albuquerque Journal New Mexican Rio Grande Sun El Hispano News	Albuquerque Tribune Journal North Los Alamos Monitor
Idaho:	Idaho Falls Post Register Times News Daily News	Idaho State Journal Idaho Statesman
Tennessee:	Roane County Newspaper	Knoxville News Sentinel

DOE also issued a press release on July 6, 1995, regarding the notice of intent. The press release was provided to general and minority market newspapers near the alternative facilities and to media outlets nationwide. Commentors from the earlier environmental assessment process were notified by mail of the DOE effort to begin preparing an EIS.

Eight EIS scoping meetings were conducted in four communities near alternative sites -- two each in Idaho Falls, Idaho (July 24, 1995); Oak Ridge, Tennessee (July 26, 1995); Albuquerque, New Mexico (July 31, 1995); and Los Alamos, New Mexico (August 1, 1995).

The scoping meetings were conducted by a neutral moderator and the format of the meetings included: 1) informational presentations on the purpose and need for the production of the medical isotopes, the proposed alternatives for the production process, medical applications for the isotopes, initial considerations for potential environmental impacts and the NEPA process; 2) a question and answer period in which EIS project representatives responded to project-related questions from the public; and 3) a public comment session during which members of the public offered formal comments on issues they deemed appropriate for review in the scope of the EIS. All the proceedings of the scoping meetings were recorded by a court reporter and transcribed for public record. An informational poster session complemented the scoping meetings. Informational materials, including documents and references, and a brochure on the proposed project were disseminated at the scoping meetings.

The DOE accepted scoping comments both orally and in writing at the public meetings. Written comments were also accepted by mail. The public comment period for the scoping of the EIS concluded on August 7, 1995.

DOE public reading rooms and selected public libraries in communities near sites considered in the EIS were provided EIS documents, reference materials, copies of public notices, written public comments, and the transcripts of the scoping meetings. These reading rooms and libraries include:

DOE Headquarters
Freedom of Information
Reading Room 1E-190
Forrestal Building
100 Independence Ave., S.W.
Washington, D.C. 20595
(202) 586-6020

Los Alamos National Laboratory
Community Reading Room
1450 Central Ave., Suite 101
Los Alamos, New Mexico 87544

Oak Ridge Operations Office
Public Reading Room, 112
55 Jefferson Circle
Oak Ridge, Tennessee 37831
(615) 241-4780

Nuclear Reactor Laboratory
Massachusetts Institute of Technology
138 Albany Street
Cambridge, Massachusetts 02139

National Atomic Museum
Building 20358
Wyoming Blvd.
Kirtland AFB, New Mexico 87185

Idaho Operations Office
Idaho Public Reading Room
1776 Science Center Drive
Idaho Falls, Idaho 83402
(208) 526-0271

Library
Georgia Institute of Technology
Atlanta, Georgia 30332-0900

Research Reactor Facility, Room 229
Research Park
University of Missouri-Columbia
Columbia, Missouri 65211

Rhode Island Nuclear Science Center
South Ferry Road
Narragansett, Rhode Island 02882

Oral comments were presented by 26 people at the scoping meetings, three of whom also submitted written comments, and 19 written comments were submitted by people who did not offer oral comments. A total of 234 comments were identified among nine comment categories. The comments came from a broad range of sources including individuals, citizen organizations, and state and local governments.

The comments received during the scoping phase were considered in the development of the *Medical Isotopes Production Project: Molybdenum-99 and Related Isotopes Environmental Impact Statement Implementation Plan* issued in September 1995. The Implementation Plan reports the results of the environmental impact statement scoping process, and provided guidance for the preparation of the Draft EIS. A notice of availability of the implementation plan was published in the *Federal Register* on October 30, 1995 (60 FR 55249), and the release of the Implementation Plan was announced through a DOE News Brief. The Implementation Plan was distributed to interested parties through a DOE mailing to individuals, organizations, Indian Tribal governments, and local, state and federal agencies. The mailing was assembled, in part, from the lists of parties who registered at the scoping meetings, commented during the earlier environmental assessment process or had otherwise contacted DOE concerning the proposed project.

On December 22, 1995, DOE published a notice of availability in the *Federal Register* (60 FR 66542-66543) for the *Medical Isotopes Production Project: Molybdenum-99 and Related Isotopes Draft Environmental Impact Statement* (DOE/EIS-0249D). During the week prior to the formal release of the document, DOE mailed copies of the Draft EIS to stakeholders and interested parties. In addition to the *Federal Register* notice (which also provided the public hearing schedule for comments on the Draft EIS), DOE provided public notice through a December 21, 1995, press release and the placement of informational advertisements in local newspapers, as previously done with regard to the scoping meetings. The issuance was also announced through the Internet on DOE's home page.

Copies of the Draft EIS were provided to the DOE public reading rooms and the selected public libraries listed above.

The period for public comment on the Draft EIS was December 22, 1995 through February 9, 1996. Due to the holiday season being observed during the comment period, DOE extended the comment period to 49 days.

Eight public hearings were conducted to receive comments on the Draft EIS, two each in Idaho Falls, Idaho (January 17, 1996); Oak Ridge, Tennessee (January 25, 1996); Albuquerque, New Mexico (January 30, 1996); and Los Alamos, New Mexico (February 1, 1996). The public hearings were conducted by a neutral moderator and the format of the meetings included: 1) informational presentations on the content of the Draft EIS, medical applications for the isotopes, and the NEPA process; 2) a question and answer session in which EIS project representatives responded to project-related questions from the public; and 3) a public comment session during which members of the public offered formal comments on the Draft EIS.

Concurrent to the formal proceedings, "quiet rooms" with tape recorders were made available for individuals wishing to offer comments privately or without waiting for the completion of agenda items in the hearing session. All the proceedings of the public hearings were recorded by a court reporter and transcribed for public record, along with taped comments from the quiet rooms. An updated informational poster session complemented the public hearings. Informational materials, including documents and references, and an updated brochure on the proposed project were disseminated at the public hearings.

The public comment period on the Draft EIS resulted in oral comments from 61 people at the public hearings, and 96 individuals and organizations submitted a total of 101 comment letters and written statements. A total of about 750 comments were identified. The comments came from a broad range of sources including individuals, citizen organizations, and state and local government agencies. Copies of the comment letters and hearing transcripts were provided to the public libraries and reading rooms listed above. Comments received on the Draft EIS were considered in preparing the Final EIS. Changes to the Draft EIS, either in response to public comment or to correct technical information, are denoted by a change bar in the margin.

In addition to the opportunities for involvement by the general public, DOE representatives engaged in a series of small group meetings with stakeholders known to be interested in the project. The purpose of the small group meetings was to offer more detailed information on the proposed project and to receive more personal characterizations of the public's interests than what might generally be portrayed in written word or in front of a larger audience. The small group meetings were informal in nature. The views expressed by the participants were not entered into the formal comment record, as other mechanisms for official comment (public hearings and written comments) were available to all. Nevertheless, points of discussion raised in the small group meetings were considered by DOE for incorporation in the EIS process where appropriate.

DOE issued a Draft EIS on December 22, 1995, and held a formal public comment period on the draft through February 9, 1996. Two public hearings were held at or near each of the four alternative locations during the comment period. Comments received and DOE's responses to those comments are found in the second volume of this EIS.

1.4.2 Changes from the Draft EIS

Changes to the Draft EIS, either in response to public comment or to correct technical information, are denoted by a change bar in the margin. All comments received, along with the Department's responses to those comments, are reproduced in the Comment Response Document (Volume II of this EIS). Comments that resulted in notable changes to the EIS addressed the following topics:

- **Need for the Project** - Some commentors questioned why the Department has proposed to produce Mo-99 when other Mo-99 production initiatives (such as Nordion's plan to build the Maple I and II reactors) are planned or are underway. The Department further investigated these other Mo-99 production initiatives and, to reflect their current status, updated Sections 2.0 and 3.2.
- **The Preferred Alternative** - Multiple commentors questioned the viability of and the rationale for identifying Annular Core Research Reactor at Sandia National Laboratories/New Mexico as the preferred alternative. Section 3.3.1.1 was revised to provide further insight into the Department's rationale for identifying the preferred alternative.
- **Cost of Alternatives** - Several commentors noted that the cost of the preferred alternative was not lowest among the four reasonable alternatives, and that the estimated cost for the Idaho and Oak Ridge alternatives should be further investigated. The EIS Team worked with the respective sites to develop additional cost data, and Section 5.22 has been revised to include this new data and to clarify the bases for the cost estimates.

- **Privatization of Mo-99 Production Facility** - Several commentors requested that the Department clarify its intent regarding the future privatization of any Mo-99 production capability that it may decide to establish. Section 2.0 has been revised to clarify the privatization discussion and to include a brief discussion of the Moly-99 project's relationship to the Department's National Isotope Strategy.
- **Shipment of Mo-99 to Nordion** - Organizations associated with the radiopharmaceutical industry commented that the Department should consider shipping Mo-99 to Nordion for final processing, quality assurance testing, and distribution. While shipment of Mo-99 to Nordion was included as a shipment option in the Draft EIS, the Summary, Section 5.11, and Appendix B of the Final EIS were modified to present this option more clearly.
- **Water Use** - Several organizations from New Mexico and other individual commentors questioned the wisdom of selecting Sandia as the preferred site, given recent reports that increased water use in the Albuquerque area could result in shortages and could even cause the city to sink (due to draining of the aquifer). Section 5.16 was revised to clarify and put into perspective the amount of water that would be used in the proposed project.
- **Required Modifications at the Power Burst Facility** - In response to comments from Idaho-based commentors, Section 3.3.4.9 was revised to clarify the modifications required to produce Mo-99 in the Power Burst Facility. These include modifications to the reactor central cavity, removal of transient control rods, and installation of coolant flow balance valves.
- **Site Descriptions** - Several commentors provided comments regarding the descriptions of the affected environment around the four sites under consideration. Chapter 4 was revised as appropriate to incorporate these comments.
- **Editorial Changes** - Multiple editorial changes were made to the EIS as a result of internal review and public comments.

1.5 Next Steps

After considering the comments received, DOE revised the EIS, as appropriate, and issued this Final EIS. The FEIS will be distributed in a manner similar to that of the Draft EIS, and will be sent to all parties who commented on the Draft EIS.

Following completion of the FEIS (but at least 30 days after the notice of availability of the FEIS is published in the *Federal Register* by the U.S. Environmental Protection Agency), DOE will issue a Record of Decision. The Record of Decision will specify which alternative (or alternatives) is environmentally preferable. In addition to the environmental impacts analyzed in this FEIS, the decision will be based on cost, programmatic, policy, national need, and other considerations.

If mitigation measures, monitoring, or other conditions are adopted as part of DOE's decision, they will be summarized in the Record of Decision, as applicable, and included in a mitigation action plan. The Record of Decision and mitigation action plan, if needed, will be placed in each alternative site's public reading room and will be available to interested parties upon request.

1.6 Relationship of the MIPP-EIS to Other DOE NEPA Documents

NEPA documents that have either been prepared, or are in preparation by DOE, for activities related to the proposed action include:

- *Programmatic EIS for Waste Management* evaluates the DOE complex-wide long-term waste management policies and practices. The notice of availability for the Draft EIS was published on September 22, 1995. Any waste generated by Mo-99 production would be managed consistent with the Record of Decision from DOE's complex-wide Programmatic Environmental Impact Statement (PEIS) for waste management.
- *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Restoration and Waste Management Programs Final Environmental Impact Statement* evaluates the management of DOE-owned spent nuclear fuel. The Record of Decision was published in the *Federal Register* on June 1, 1995. The small quantity of spent nuclear fuel generated from use of a reactor in the production of Mo-99 would be managed in accordance with the Spent Nuclear Fuel-Programmatic Environmental Impact Statement (SNF PEIS) Record of Decision.
- *Los Alamos National Laboratory Site Wide Environmental Impact Statement* will analyze the cumulative impacts of operations and planned activities foreseen at LANL within the next 5 to 10 years (notice of intent published on May 12, 1995, 60 FR 25697). The preferred alternative and one additional alternative considered in this MIPP-EIS would involve the use of facilities at LANL. The preferred alternative proposes to use the Chemistry and Metallurgy Research Facility to fabricate the targets. Another alternative examined in this MIPP-EIS considers the use of the Omega West Reactor (for irradiation of targets) and of the Chemistry and Metallurgy Research Facility (for target fabrication and processing).
- *Draft Environmental Impact Statement for the Nevada Test Site and Other Offsite Test Locations Within the State of Nevada* will analyze the cumulative impacts of operations and planned activities foreseen at the Nevada Test Site. The Draft EIS was issued for public review in January 1996. Low-level waste from Mo-99 production is included as part of the impact analysis in the sitewide Nevada Test Site EIS.
- *Draft Environmental Assessment for Sandia National Laboratories/New Mexico Offsite Transportation of Low-Level Radioactive Waste* will evaluate the shipment of existing inventories of low-level waste accumulated at SNL/NM and new low-level waste projected to be generated at SNL/NM.

Low-level radioactive waste, generated by the production of Mo-99 at SNL/NM and analyzed in the MIPP-EIS, will be included in the projected quantities identified in the proposed EA.

- *Environmental Assessment for the Chemistry and Metallurgy Research (CMR) Building Upgrades at Los Alamos National Laboratory* was prepared to evaluate safety upgrades to the facility. The purpose of the upgrades is to reduce risk, enhance the safety margin, and provide for the continued safe, reliable, and effective use of the facility in support of Laboratory missions. The Department is reviewing comments received during the public comment period and expects to decide if the Environmental Assessment supports a finding of no significant impact in 1996. The Chemistry and Metallurgy Research Facility is being considered for use in both the preferred alternative (to be used for target fabrication activities) and the LANL Omega West Reactor alternative (target fabrication and processing). The medical isotopes project activities at the Chemistry and Metallurgy Research Facility would proceed independently of the building upgrades.

2.0 Purpose and Need for Action

For more than 40 years, the U.S. Department of Energy (DOE) and its predecessor agencies have produced and distributed isotopes for medical and industrial applications through DOE's national laboratories. In 1990, Congress established the Isotope Production and Distribution Program to consolidate all existing DOE isotope production activities under one program.

Among other activities, the DOE Isotope Production and Distribution Program has responsibility for ensuring that the U.S. health care community has access to a reliable supply of molybdenum-99 (Mo-99). Mo-99 is a short-lived radioactive isotope of molybdenum. In just a few days after its production, Mo-99 decays to form metastable technetium-99 (Tc-99m), the most widely used medical radioisotope in the U.S.

Tc-99m has broad nuclear medicine applications in the areas of diagnostic procedures and medical laboratory tests. According to a report issued to the U.S. House of Representatives Subcommittee on Energy and Environment, a total of approximately 38,000 diagnostic procedures involving radioactive isotopes are performed each day in the United States. Most of these procedures use Tc-99m. By chemically attaching the Tc-99m to a selected carrier agent, it is possible to direct the isotope to a specific area of concern, such as the bones, brain, heart, kidneys, liver, lungs, and thyroid gland. From its target location in the body, Tc-99m emits gamma radiation that is received by gamma camera imaging equipment. The images created provide physicians with detailed information about conditions and functions in the body that could otherwise be obtained only by performing invasive exploratory surgery. Tc-99m-based radio-pharmaceuticals help provide an assessment of organ function and detection of tumor metastases in the body.

Tc-99m is the isotope of choice for most diagnostic procedures because its short physical half-life (6 h) minimizes the radiation dose received by the patient, because the characteristics of its radioactive emissions allow for quick and accurate diagnosis of certain abnormal conditions in the body (as well as verification of corrective actions) and because it can be combined with many different carriers to concentrate in different parts of the body. No other isotope has been found to offer a better combination of short half-life, optimum energy for gamma imaging, low patient dose, and versatility.

The short half-lives of Mo-99 and Tc-99m (66 h and 6 h, respectively) make these isotopes highly perishable. In order to provide a reliable supply for medical use, it is critical that production and distribution be maintained essentially on a continuous basis.

The Atomic Energy Act of 1954 authorized the Atomic Energy Commission to produce and make available radioisotopes for medical and scientific purposes. From the mid-1950s through 1966, the Atomic Energy Commission supplied Mo-99 produced at the Oak Ridge Research Reactor in Tennessee and in reactors at the Brookhaven National Laboratory in New York. The Atomic Energy Commission withdrew from Mo-99 production when commercial production was initiated in the U.S. by Union Carbide Nuclear

Corporation at a small reactor in Tuxedo, New York. From 1970 to 1989, Cintichem, Inc. produced Mo-99 at the Tuxedo, New York, reactor and provided approximately half of the Tc-99m used in the U.S. In 1989, Cintichem decided to shut down and decommission its reactor.

In November 1991, DOE purchased the Cintichem technology and equipment for \$750,000, with an agreement to pay Cintichem a 4% royalty on the first 5 years of sales of Mo-99 and other isotopes produced by use of the Cintichem process. In addition, DOE agreed to accept the spent nuclear fuel from the Cintichem reactor. Subsequently, the Cintichem reactor was decommissioned and the spent nuclear fuel was transported to the DOE's Savannah River Site for storage.

The loss of the Mo-99 production capability at Cintichem left the U.S. totally reliant upon a single foreign source, Nordion International, located near Ottawa, Canada. Nordion receives bulk Mo-99 from Atomic Energy of Canada Ltd. (AECL). Nordion presently produces essentially all of the Mo-99 sold in the U.S., and an estimated 85% of the Mo-99 sold worldwide. The remaining 15% is produced by a variety of sources, most of which are located in Europe.

Prior to 1993, AECL operated two reactors that were available for the production of Mo-99. In 1993, one of the two Canadian reactors was permanently shut down, leaving only the second reactor operating. Any shutdown or extended outage of this nearly 40-year-old reactor could jeopardize the U.S. supply of Mo-99. In April 1995, this reactor suffered an unplanned shutdown for four days. European sources were able to increase their production temporarily to cover the European demand usually supplied by Nordion, and Nordion had sufficient product in process to meet the U.S. demand during this period. However, because Mo-99 has such a short half-life, making long-distance shipping difficult, and because European sources did not have sufficient capacity to meet both U.S. and European needs, shortages would likely have occurred in the U.S. if the Canadian reactor had remained out of service.

Although Mo-99 can be produced by different processes, such as target irradiation in a reactor or in an accelerator, only the Cintichem process and the proprietary process used by Nordion have been approved by the U.S. Food and Drug Administration (FDA) for Mo-99 sold in the U.S. Both processes use Mo-99 produced in a reactor. The Nordion process results in substantially greater quantities of liquid radioactive waste and mixed waste than the Cintichem process. Waste generated by the Cintichem process is primarily solid waste, which is much easier to manage and dispose. In both processes, the Mo-99 is shipped by air to radiopharmaceutical manufacturers, where the product is packaged as Mo-99/Tc-99m generators, so that Tc-99m can be extracted for use at the medical facilities. The Cintichem process can also be used to produce certain other radioisotopes (iodine-131 and xenon-133) that have medical applications. Iodine-125 was also produced by Cintichem through irradiation of xenon-124.

DOE proposes to establish, as soon as practicable, a domestic capability to produce a continuous supply of Mo-99 and related medical isotopes for the U.S. medical community. The purpose of the proposed action is to ensure a reliable domestic supply of Mo-99, an important medical isotope. The near-term goal (over the next 5 to 10 years) is to provide a backup capability to production in Canada by supplying a baseline production level of 10 to 30% of the current U.S. demand for Mo-99. This goal would include the

capability to supply 100% of the U.S. demand, should the Canadian source become unavailable. Because of the potential for Mo-99 shortages, it is essential to establish a backup capacity as soon as practicable. If and when private industry can ensure a reliable supply of Mo-99, the Department will reassess its need to maintain a Mo-99 production capability.

The U.S. medical community uses about 60% of the worldwide supply of Mo-99/Tc-99m, yet has no current domestic production source for these isotopes. Because the worldwide medical radioisotope market is influenced by forces other than narrow market forces, full cost recovery of investment is often not feasible. In addition to market vagaries, the uncertainties and liabilities associated with licensing, constructing, and operating a nuclear reactor have prevented, and will likely continue to prevent, private companies in the U.S. from developing a domestic source of Mo-99 to replace the Cintichem reactor. Nordion intends to build two modern 10-MW reactors in Canada, as replacements for the existing reactor.^(a) However, until these reactors are built, a window of vulnerability will exist for the U.S. medical community. DOE commissioned a study entitled an *Independent Assessment of the DOE Plan to Establish a United States Production Source for Molybdenum-99*, conducted by Integrated Resources Group, Inc., and JUPITER Corporation, dated September 30, 1994, which concluded "there is a critical need for a stable supply of Mo-99 in the United States" (Savoie and Singh 1994).

Although Mo-99 production sources in Europe could increase their production rates in the event of a shutdown of the Canadian reactor, Savoie and Singh 1994 found that "[while the European sources] do offer some potential for the near-term [supply of Mo-99]...European capacity can only supply a portion of the U.S. demand."

If the Canadian production source were to become unavailable, the supply of Mo-99 available to the U.S. would be substantially reduced or eliminated. A shortage of Mo-99 would limit the diagnoses of thousands of medical patients in the U.S. each day. A reduction in Mo-99 supply could also result in a cost increase to patients for diagnostic procedures that involve Tc-99m.

Because the U.S. medical community has been without a reliable backup supply of Mo-99 since the shutdown of one of the Canadian reactors in 1993, DOE is addressing the critical need to provide such a backup. In Senate Report No. 103-291 accompanying the Energy and Water Development Appropriations Act, 1995, the Committee on Appropriations stated the

"United States is fully dependent for 100% of the supply of Mo-99 and Tc-99m, both important to nuclear medicine, on sources in Canada which produces (sic) these isotopes in aging facilities. Of particular concern is the lack, since 1990, of a domestic source of Mo-99, an isotope used to produce

(a) Nordion communication to Nuclear Medicine Professionals on November 10, 1995. Nordion International, Inc., 447 March Road, Kanata, Ontario, Canada.

Tc-99m which is used in approximately 36,000 medical diagnoses per day. The committee notes that the Department is taking steps to...produce Mo-99 and related medical isotopes to ensure that there are no inadequacies of supply for domestic use. The committee supports this effort and wishes to be kept informed as the Department progresses."

The need for a domestic production source for Mo-99 has been echoed by the U.S. medical and scientific communities. Response to a statement in a December 1994 report by the Institute of Medicine Committee on Biomedical Isotopes stating the short term Mo-99 supply situation is "no longer precarious" has been particularly strong. In a February 1995 report, Senior Scientists and Engineers stated "in our only disagreement with that distinguished [Institute of Medicine] committee, we believe that their report is over optimistic on the Mo-99 situation, now and future..., and that "the Mo-99 problem...must be [solved] if the U.S. is to have a reliable supply of its most important non-military isotope." Also, the *Position Statement on Isotope Availability* issued by the Society of Nuclear Medicine and the American College of Nuclear Physicians in May 1995 stated, "it is particularly urgent that the U.S. Government work to establish a reliable uninterrupted supply of Mo-99, as the source of Tc-99m, the main radioactive isotope used in diagnostic Nuclear Medicine."

For the reasons previously stated, and as recommended by Savoie and Singh (1994), DOE proposes to "move immediately to narrow this [short-term] window of risk," regarding the domestic supply of Mo-99. DOE's long-term goal (beyond 5 to 10 years) is that production of Mo-99 in the U.S. should be conducted by the private sector. DOE is not addressing the long-term in this environmental impact statement. DOE does, however, encourage the development of private sources in the U.S. for long-term production of Mo-99. The Department could then withdraw from markets that are reliably supplied.

If DOE proceeds with the near term production of Mo-99 and related medical isotopes using government facilities and equipment, the Department would eventually explore the possibility of private sector participation consistent with the U.S. Department of Energy National Isotope Strategy (DOE 1994a). The Department would consider the potential sale or lease of certain of its facilities to private sector entities if, by such action, isotope production and delivery would be enhanced. The Department's objectives would be to encourage the private sector to play a greater role in isotope supply and to decrease the Government's cost and involvement. Any environmental reviews and actions related to future private sector involvement would be performed as required by law.

3.0 Alternatives

The U.S. Department of Energy (DOE) proposes to establish, as soon as practicable (in about 1 to 3 years), a domestic capability to produce a continuous supply of molybdenum-99 (Mo-99) and related medical isotopes for the U.S. medical community. The purpose of the proposed action is to ensure a reliable domestic supply of Mo-99, an important medical isotope. This section describes the alternatives that were considered for the production of Mo-99 and related medical isotopes.

3.1 Approach to Determine the Reasonable Alternatives

To determine the reasonable alternatives, DOE identified specific technical criteria necessary to satisfy the purpose of, and need for, the proposed action. These criteria were used to evaluate alternative facilities for both Mo-99 production and separation.

3.1.1 Molybdenum-99 Production Facility Needs

- Facility must be operating or capable of operating in the near term.
- Production method must allow the separation facility to provide approximately 3000 6-day curies (Ci) per week to the radiopharmaceutical houses to satisfy the U.S. demand for Mo-99. A 6-day curie is the amount of activity remaining after a given product has been allowed 6 days to decay.
- Facility must have the handling capability to support removal of the product from the facility.
- Periodic scheduled maintenance outages must be reliably accomplished in ≤ 6 days.
- Facility operation must be capable of using a U.S. Food and Drug Administration (FDA)-approved process for Mo-99 production.
- Facility must be able to package and transport the production facility product, if required, to a facility that can chemically process the product.

3.1.2 Molybdenum-99 Separation Facility Needs

- Facility must be capable of providing shielded and sealed rooms sufficient to support reliable Mo-99 production (including separation and environmental control equipment, remote handling equipment, and a room for a quality control facility).

- Facility must be capable of providing adequate ventilation systems to manage any hazardous gases produced or released during the separation process (separate zones, differential pressures, and filters).
- Facility must be located so that timely packaging and shipment of the Mo-99 product from the facility will ensure that the activity and purity requirements of the product are maintained (10,000 Ci Mo-99 per gram of product upon delivery to the customer).
- Facility must be able to manage the radioactive waste that is generated during the separation.
- Facility must be able to employ an FDA-approved process for Mo-99 separation.
- Facility must be capable of reliably separating commercially desirable ancillary radioactive isotopes (7 days/week) consistent with an FDA-approved Mo-99 separation process.

Either an accelerator, a solution-fueled nuclear reactor, or a solid-fueled nuclear reactor could be used to produce Mo-99. However, the technology necessary to produce Mo-99 in an accelerator or in a solution-fueled reactor is not sufficiently developed to satisfy the production criteria listed. Therefore, the reasonable alternatives described in this section all involve the use of a solid-fueled reactor as the Mo-99 production facility.

Two processes are approved by the FDA for the production and separation of Mo-99 sold in the U.S., both of which involve use of a solid-fueled reactor. They are the Cintichem process and the process used by Nordion International in Canada. Only one of the alternatives considered, the University of Missouri Research Reactor, would use the Nordion process. This alternative was not considered reasonable because it could not satisfy the production and separation facility criteria listed. All of the reasonable alternatives would use the Cintichem process.

The Cintichem process involves four steps (see Figure 3-1). The first step is target fabrication. In this step highly enriched uranium, 93% enriched in the fissile isotope uranium-235, is coated on the inside of a stainless steel tube. The tube is then sealed at each end. This step is conducted remotely inside a controlled-atmosphere facility, such as a glove box. (The Department of Energy has issued a "sources sought" notice to determine if there are companies interested in target fabrication [CBD 1995]. Responses to the request would be evaluated prior to a determination of whether to proceed with a procurement regarding privatization of target fabrication, and National Environmental Policy Act [NEPA] documentation would be prepared as appropriate.)

The second step is target irradiation in the Mo-99 production facility (a solid-fueled reactor). A target is usually irradiated in a reactor for about a week, and then is removed for processing.

The third step is target processing in the Mo-99 separation facility. In this step, the irradiated target is placed into a heavily shielded facility known as a hot cell. The top of the target is punctured, the gases inside the target are removed, and a chemical solution is poured into the target. This chemical solution

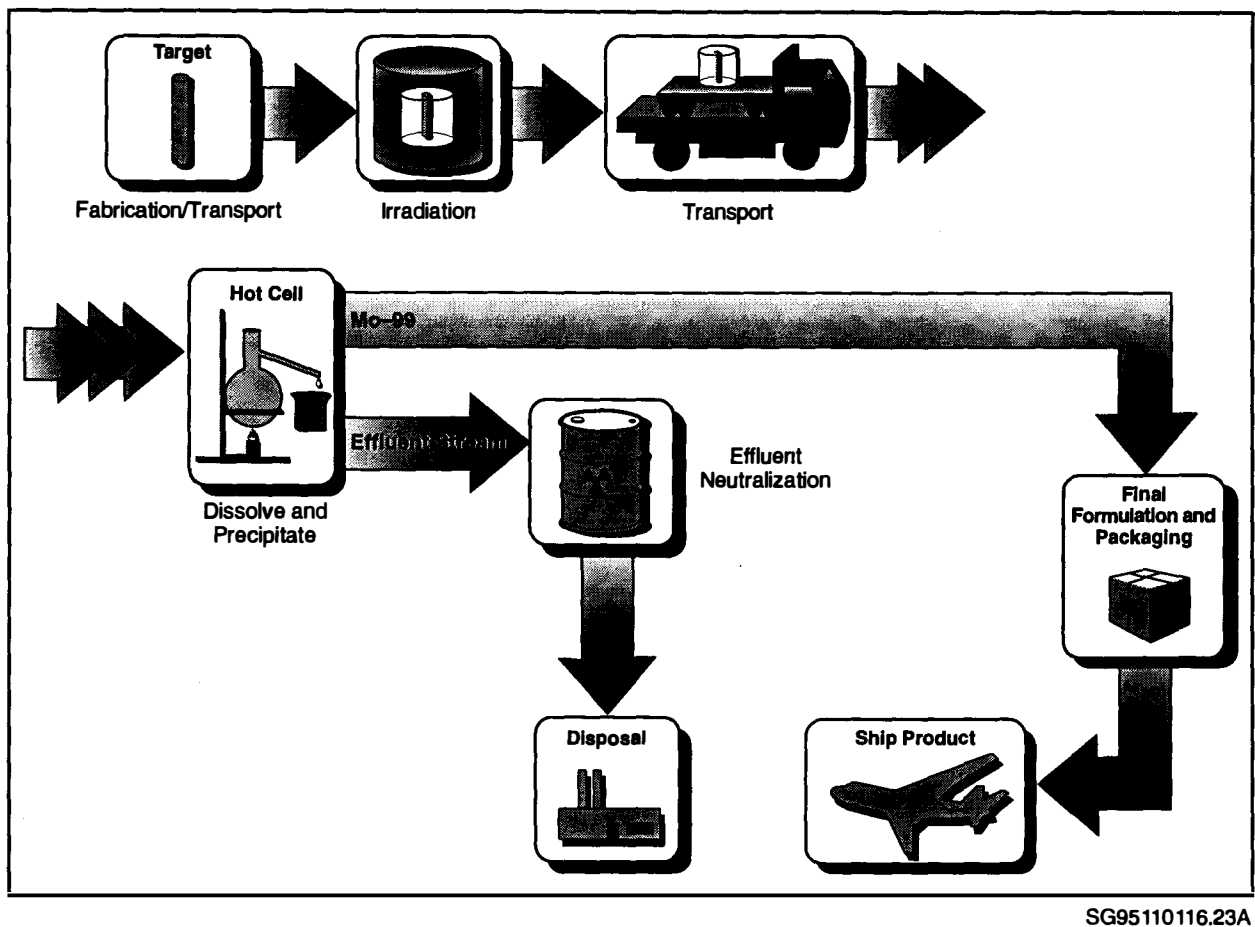


Figure 3-1. Molybdenum-99 Production Process

dissolves the highly enriched uranium coating from the inside of the target. The chemical solution is then filtered to remove the molybdenum, which is packaged for shipment to the radiopharmaceutical companies. A more detailed description of this step is provided in Appendix A.

Waste stream management is the fourth step. Materials used in the separation of the Mo-99 product become waste during the processing. The Idaho National Engineering Laboratory (INEL) and Los Alamos National Laboratory (LANL) are capable of handling, processing, and storing, entirely onsite, the waste generated from Mo-99 production. Sandia National Laboratories/New Mexico (SNL/NM) and Oak Ridge National Laboratory (ORNL) would ship waste generated from Mo-99 production to the Nevada Test Site, which historically has been the site for disposal of low-level waste.

The DOE intends to produce a baseline quantity of Mo-99 (about 10% to 30% of U.S. demand) to maintain the capability to respond to shortages in domestic Mo-99 supply. Because the DOE intends to

produce Mo-99 even when the Canadian source is supplying Mo-99, periods may occur when DOE is unable to sell the Mo-99 it produces. In this case, the unsold Mo-99 would be disposed of as low-level radioactive waste at the same disposal site as other low-level wastes generated during Mo-99 production.

Two additional medical isotopes produced from fission, xenon-133 and iodine-131, can be separated from the waste streams of the Mo-99 process. Xenon-133 is used in the diagnosis of lung maladies; iodine-131 is used in the diagnosis and treatment of thyroid conditions, such as Graves disease. The Drug Master Files for these isotopes are structured for an initial extraction from the waste stream of a Mo-99 production process. Separate hot cell facilities, or at least several additional process stations within hot cells, would be required to perform these separations as concomitant operations with the Mo-99 process.

The DOE has given LANL the task of reproducing and refining the Cintichem target fabrication process. This initiative is currently being conducted in the Chemistry and Metallurgy Research Wing 9 Facility. A proof of process scale production facility has been completed. Associated quality assurance and quality control equipment and procedures are also being developed. These procedures and methods are used to ensure that completed targets would not leak during irradiation, the inner wall uranium coating would be uniform, and the appropriate amount of material had been plated on the target inner wall. This work, when completed (about 1 month after the Record of Decision for this FEIS), could be reproduced at most sites as a turn-key process.

LANL has also been tasked by the DOE to assist SNL/NM in the development of the Cintichem separation chemistry process, which would be applicable at all reasonable alternative sites. This initiative is currently ongoing at LANL and SNL/NM.

Iodine-125, an isotope used in radio-immunoassay activities, can also be produced at the facility selected for Mo-99 production. The iodine-125 process requires a separate target irradiation. The iodine-125 isotope can be made through irradiation of xenon-124. Production of this isotope requires separate irradiation locations in the reactor or the reactor shield. It would also require separate hot cell facilities in which to conduct the chemical separation and purification processes.

The focus of the proposed project is the production of Mo-99. Iodine-125, iodine-131, and xenon-133 could be produced at any of the sites to offset the costs of Mo-99 production, but are in less demand by the medical community than Mo-99. Therefore, the focus of the discussion in the remainder of this section is on the production of Mo-99.

3.2 No Action Alternative

3.2.1 Description of the Alternative

Under this alternative, DOE would not establish a U.S. production source for Mo-99. The U.S. would continue to rely on Nordion International, a Canadian firm, to supply its Mo-99 needs. Potential changes

to the currently existing conditions include the construction of new Mo-99 production reactor(s) and a new separation facility in Canada, FDA approval of other foreign Mo-99 production processes, and commercialization of alternative Mo-99/Tc-99m production technologies.

3.2.2 Impacts of the No Action Alternative

The current demand for metastable technetium-99m (Tc-99m) in the U.S. requires a weekly supply of approximately 3000 6-day Ci of Mo-99. Currently, the entire U.S. supply of Mo-99 is produced in Canada by Nordion International, using a single reactor, the National Research Universal (NRU) reactor. Under the no action alternative, the U.S. medical community would continue to rely on this source of supply.

The current supply of Mo-99 from Canada would be interrupted if the NRU reactor experienced a mechanical failure or were shut down for any reason. The NRU reactor must operate continuously for 12 or 13 days of each 15-day operating period in order to maintain a continuous supply of Mo-99. Down time is normally required for maintenance, repairs, and target replacement. This operating schedule has been maintained for many years to meet the U.S. and Canadian demands for Mo-99, and to ship Mo-99 to numerous other foreign countries.

An interruption of the continuous supply of Mo-99 from Canada would have serious impacts on the practice of diagnostic nuclear medicine in the U.S. More than 90% of all diagnostic imaging procedures rely on Mo-99 generator-supplied Tc-99m. These procedures involve medical tests for renal (kidney) function, bone scans for cancer and other abnormalities, liver and bile duct function, heart disease and defects, brain cancer, blood flow in stroke patients, and diagnoses for a variety of other health conditions. The discontinuation of physicians' ability to perform such necessary diagnostic tests would seriously undermine their ability to diagnose and treat many different diseases. For many of these tests, there is no alternative method of analysis. About 36,000 patients could be affected for each day of interrupted supply.

If the NRU reactor is shut down, it might not be restarted. The reactor was commissioned in 1957 and, although an aggressive maintenance program is in place to keep it operating, no plans exist to continue operation beyond the year 2000 because of the reactor's age and the isotope separation waste storage capacity. Any major problem at the reactor requiring significant time and resources to repair would likely result in a permanent shutdown, terminating this source of supply.

Nordion International Inc. and Atomic Energy of Canada Ltd. (AECL) (the Crown corporation that operates the NRU reactor) began planning and construction of (initially one and now two) new isotope production reactors (Maple I and Maple II) to replace the NRU reactor for Mo-99 production. These facilities would use a Mo-99 production and separation process similar to the Cintichem process to reduce the amounts of radioactive waste generated. However, AECL decided to halt construction of the Maple reactor complex and processing facility in 1993 after a legal and financing dispute with Nordion and its parent company, MDS Health Group Ltd., of Canada. MDS Health Group Ltd. subsequently filed a breach of contract lawsuit against AECL, and the two sides agreed to arbitration hearings to resolve the dispute (Rojas-Burke 1995). The dispute has been mostly resolved, but Nordion has not yet made a formal

| announcement to resume construction due to a disagreement with the Canadian government regarding the
| tax treatment of the new reactors. The announcement to resume construction was previously anticipated in
| the first quarter of 1995 (Savoie and Singh 1994).

| The sale in the U.S. of Mo-99 produced at the Maple reactor complex cannot begin until the facility is
| completed, licensed, and approved by the U.S. FDA for supply to U.S. pharmaceutical companies.
| Although Nordion currently plans to build two reactors, they may at some time decide to construct only
| one of the two proposed reactors. If only one reactor is built, the sole-source of supply issue would remain
| for nuclear medicine physicians in the U.S. The Nordion and AECL estimate of the time required to
| complete the necessary environmental and construction permitting, to construct and commission one of the
| reactors, and to construct the radiochemical separation facility is about three years. Construction and
| commissioning of the second reactor, if pursued, would proceed simultaneously and would be completed
| about one year after the first unit. Full-scale Mo-99 production and sale in the U.S. would probably
| require an additional several months at each of the reactors.

| Nordion estimates the cost to construct the two new reactors and the new processing facility at
| \$140 million. To finance the construction of the new reactors and hot cell, Nordion has announced that
| they intend to raise the price of Mo-99 by about 40%.

| Nordion has established a European subsidiary by acquiring the radiopharmaceutical department of
| Institute National des Radio-elements (IRE) in Fleurus, Belgium, but the IRE (fully-owned by the Belgian
| federal government) remains the owner of Mo-99 production. IRE and Nordion have signed a mutual
| Mo-99 backup agreement to avoid a complete shortage of Mo-99 in case of an unscheduled shutdown of
| the Canadian NRU reactor. However, Mo-99 from the Belgian source has never been sold in the U.S. The
| contractual backup arrangement is currently written for IRE to supply Nordion the excess capacity of its
| facility for 8 weeks.

| The IRE has produced medical and industrial isotopes since 1972. Its primary source for medical
| isotopes is the BR2 reactor at Mol, Belgium. The IRE currently uses a collaboration of four different reac-
| tors to ensure a stable supply. They are the BR2, the High Flux Reactor (HFR) at Petten, the Netherlands,
| OSIRIS at Saclay, France, and SILOE at Grenoble, France. IRE's processing of Mo-99 is centralized in
| Fleurus. The IRE runs at a normal base level of 1200 6-day Ci per week, has a capacity of 2000 6-day Ci
| per week, and can produce approximately 3000 6-day Ci per week on a short-term basis. In this case,
| approximately 1800 6-day Ci could be produced to supply the U.S. for 8 weeks under the backup arrange-
| ment with Nordion (Savoie and Singh 1994). This quantity (1800 6-day Ci) is only 60% of the current
| U.S. demand.

| It is unlikely, however, that Nordion's backup arrangement with IRE could immediately respond to a
| U.S. shortage of Mo-99. Use of the IRE source would depend on IRE's ability to obtain FDA approval.
| The IRE submitted a Drug Master File to the FDA in 1991, and Mo-99 samples were sent to the U.S.
| radiopharmaceutical companies (DuPont-Merck, Amersham Medipysics, and Mallinckrodt Medical) so
| that they could support IRE's request for FDA approval. However, the FDA approval process on the

| submittal has proceeded slowly because IRE has no established U.S. customers. IRE has informed DOE
| that IRE has a sufficient number of certified transport casks to ship the Mo-99 material from Europe
| directly to the U.S. pharmaceutical companies.

| Mallinckrodt Medical, a U.S. radiopharmaceutical company, is currently working with the HFR at
| Petten in the Netherlands to secure a backup supply for its European needs. The HFR is owned by the
| Joint Research Center of the European Community and is operated by the Netherlands Energy Research
| Foundation. It is a multipurpose reactor, previously used about 15% of the time for production of
| radioisotopes.

| Mallinckrodt would use the HFR to produce Mo-99 and recently completed an upgrade of a radio-
| chemistry processing facility at Petten to process the Mo-99. In August, 1995, Mallinckrodt received a
| license from the Dutch nuclear regulatory authority to produce medical isotopes at the Petten facility.
| Mallinckrodt has worked since that time to secure approvals from the U.S. FDA for Mo-99 generators for
| sale in the U.S. The Petten facility expects to receive back-up Mo-99 from reactors in France and,
| perhaps, Poland. The Mallinckrodt process uses clad plate uranium-235 sections as targets, similar to the
| Nordion process.

| Mallinckrodt expects to begin Mo-99 production at Petten for European customers in 1996, and for
| U.S. operations upon FDA approval. Mallinckrodt expects to be able to supply about 30% of the world
| market, but will not supply Mo-99 to other pharmaceutical companies. It does not intend to compete with
| Nordion, which is expected to supply the remaining 70% of demand. While production at the Petten HFR
| could be increased beyond European needs, it would not be expected to meet the U.S. demand in the event
| of an interruption in supply at Nordion.

| Molybdenum-99 is produced in a number of other countries. These include reactor production facilities
| in Australia, Indonesia, Japan, Peru, Argentina, Russia, China, and South Africa. For the most part,
| these represent small, government-run production facilities, and the Mo-99 is produced for local use rather
| than international export. It is not expected that any of these foreign sources could meet a significant
| portion of the U.S. demand for Mo-99/Tc-99m generators. The production capabilities are generally small
| and sporadically run. The foreign governments are reluctant to try to meet U.S. FDA requirements for
| export to the U.S., which are viewed as unreasonably costly and lengthy to pursue. International politics
| and transportation deficiencies also have major roles in limiting the ability of foreign producers to supply
| Mo-99 to the U.S.

| The Atomic Energy Corporation of South Africa has expanded its Mo-99 production capacity at its
| Safari-1 research reactor to 1000 curies per week and has commissioned a new radiochemical process line
| at its facility near Pretoria (Nucleonics Week, 1996). The product has not been approved by the U.S. FDA
| for sale in the U.S.

Thermo Technology Ventures, Inc., a U.S. company, is investigating a concept for direct production of Tc-99m using small particle accelerators (see Section 3.4.3.3). If successful, Thermo Technology Ventures may be able to supply a significant quantity of Tc-99m to the U.S. medical community by late 1999.

If DOE selects the no action alternative and does not establish a domestic supply of Mo-99, neither the government nor private industry could effectively respond to the U.S. Mo-99 needs if the Canadian source becomes unavailable. Because the production process for Mo-99 requires a properly trained staff, a technically viable reactor or accelerator, and substantial hot cells, a production source cannot quickly be established. A significant amount of planning, time, and resources is necessary to establish such capability. Schedules for establishing a production source for the four analyzed alternatives are listed in Table 3.2 at the end of this section. Budget figures for establishing a production source are listed in Section 5.3. These figures do not include sunk costs or continued operational costs.

3.3 Alternatives to Accomplish the Proposed Action

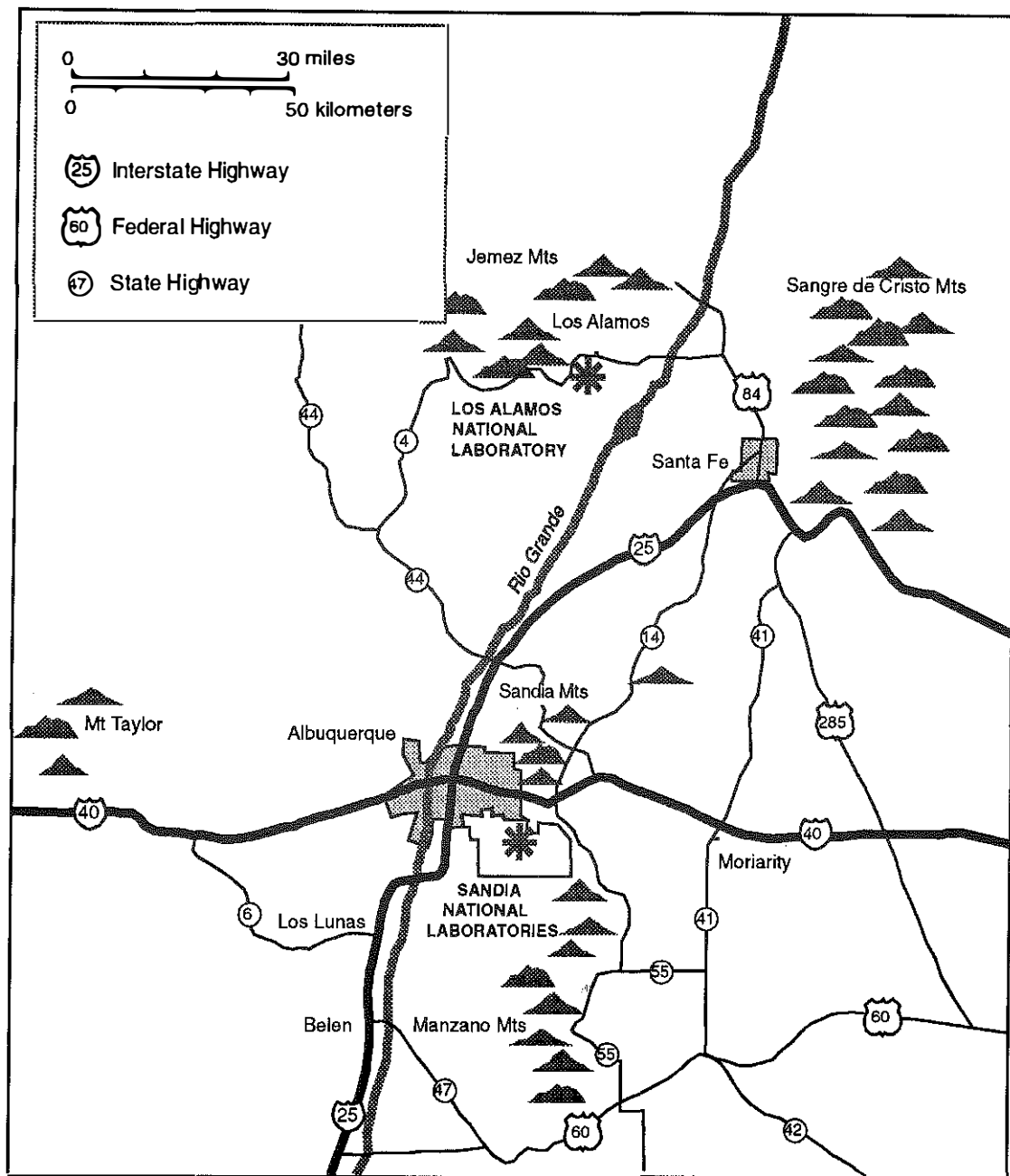
3.3.1 Annular Core Research Reactor: Sandia National Laboratories/ New Mexico and the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative--Preferred Alternative

The SNL/NM is located in Albuquerque, New Mexico, as a tenant on the Kirtland Air Force Base. The SNL/NM is a multiprogram laboratory operated for DOE by the Lockheed-Martin Corporation with facilities located in Albuquerque, New Mexico, and Livermore, California. The SNL/NM is a research and development facility and conducts programs in nuclear reactor safety, nuclear safeguards, energy research, and microelectronics. The SNL/NM has not been called upon to produce and market radioisotopes in the past. This type of mission would be new to the SNL/NM facilities.

This alternative would involve the use of existing DOE facilities at SNL/NM and LANL to produce Mo-99. The following sections describe the activities included as part of this alternative. The locations of SNL/NM and LANL are shown on Figure 3-2.

3.3.1.1 Description of the Alternative

Under this alternative, highly enriched uranium targets would be fabricated at the LANL Chemistry and Metallurgy Research Facility and then shipped to Technical Area V at SNL/NM. The targets would be irradiated in the SNL/NM Annular Core Research Reactor, removed and then processed to produce medical radioisotopes in the SNL/NM Hot Cell Facility adjacent to the Annular Core Research Reactor. The medical radioisotopes would be shipped to radiopharmaceutical companies via the Albuquerque International Airport. Low-level wastes would be shipped to the Nevada Test Site for disposal under an existing agreement.



SG95110116.21

Figure 3-2. Location of Los Alamos National Laboratory and Sandia National Laboratories

An overview of the proposed program is depicted in Figure 3-3.

The Annular Core Research Reactor/Hot Cell facility combination is the preferred alternative for target irradiation and processing because of the relatively short time required to begin initial production. The ability to produce even a small amount of Mo-99 in a short period of time is important in that FDA approval of DOE-produced Mo-99 could be obtained earlier and, if an Mo-99 shortage were to occur in the near future, DOE would be able to supply at least a fraction of the U.S. demand. The following factors also contributed to the identification of the Annular Core Research Reactor/Hot Cell Facility as the preferred alternative.

- The reactor and hot cell are currently operable, and the reactor has current safety documentation (e.g., Safety Analysis Report and Technical Safety Requirements). These factors would help reduce cost and schedule uncertainties associated with producing Mo-99. Because DOE is proposing to respond to a near term window of vulnerability in Mo-99 supply, it is important to keep uncertainties (especially schedule uncertainties) to a minimum.
- The reactor is not in use at this time, and is only expected to be needed to support defense programs in the event of a national emergency.

Under the preferred alternative, the Chemistry and Metallurgy Research Facility is the preferred target fabrication facility. This facility is in the locale of the preferred reactor and the staff are familiar with the target fabrication process. The facility also has the capability of extracting uranium from the waste streams, greatly reducing the quantity of highly enriched uranium necessary for target production. This facility was used to develop significant enhancements to the Cintichem target fabrication process; thus, the process currently exists at this facility in a prototype system.

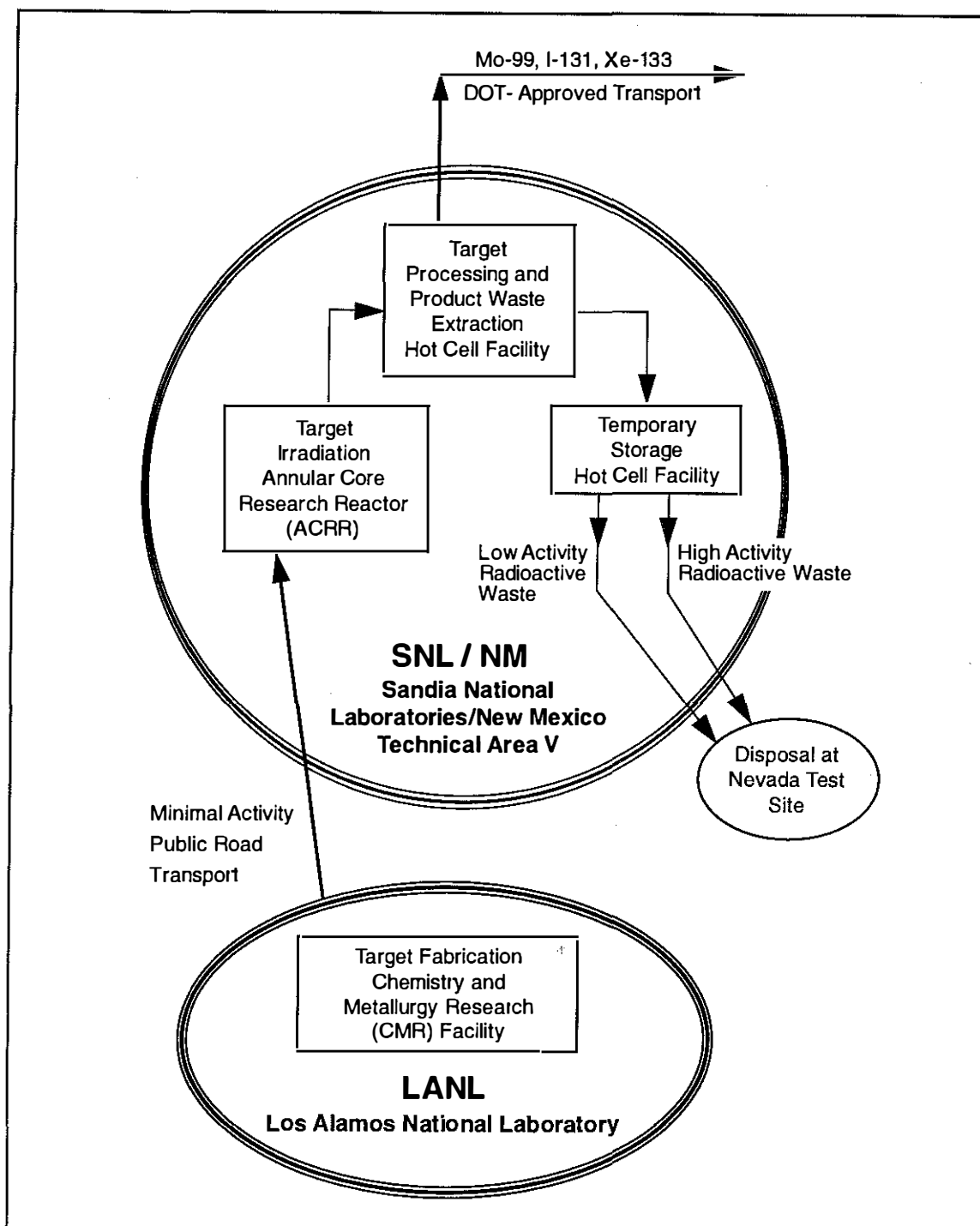
3.3.1.2 Existing Facilities

Existing facilities at LANL and SNL/NM that would be used in the production of Mo-99 include the Chemistry and Metallurgy Research Facility at LANL (target fabrication); the Annular Core Research Reactor at SNL/NM (to irradiate Mo-99 production targets), and the SNL/NM Hot Cell Facility (processing).

In its current configuration, the Hot Cell Facility would only be able to conduct limited processing activities. A new cell would be constructed within the Hot Cell Facility to enable steady state production of greater than 10% and up to 100% of the U.S. demand for Mo-99.

3.3.1.3 Target Fabrication

Target Fabrication at LANL. Target fabrication would be performed inside glove boxes that are vented through high efficiency particulate air (HEPA) filters to the stacks in the Chemistry and Metallurgy Research Facility, Wing 9. Each target would be constructed of number 304 stainless steel tubing,



SG95110116.20

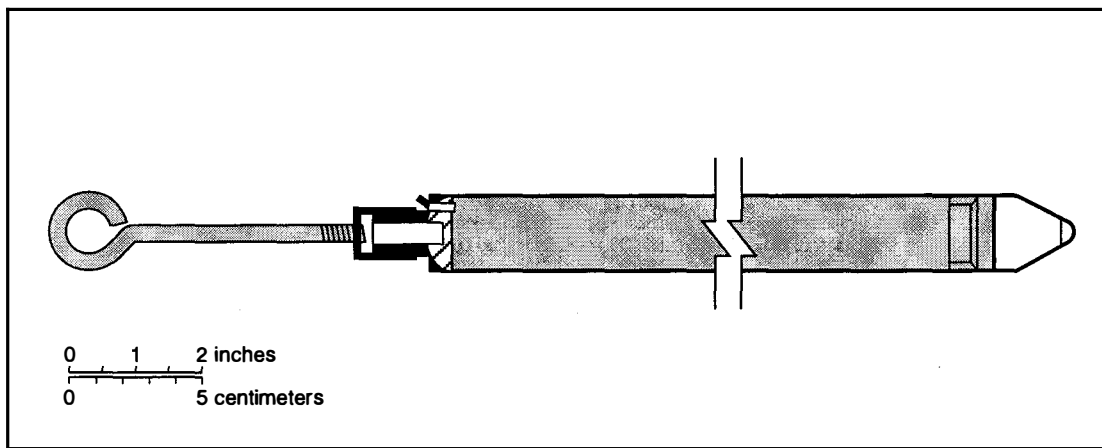
Figure 3-3. Sandia National Laboratories/Los Alamos Laboratory Isotope Production Process

approximately 51 cm (20 in.) long and 3 cm (1.25 in.) in outer diameter with a wall thickness of 0.09 cm (0.035 in.) (see Figure 3-4). Caps would be welded to close the top and bottom of the tube. The top fitting would include a thin diaphragm that contains the tube contents, until it is punctured in the fission product recovery process. The inside tube wall of the targets would be plated with highly enriched uranium (93% enriched uranium). The uranium plating would be approximately 50 microns thick and uniformly plated throughout the length of the tube. Powdered uranium oxide feedstock would be dissolved in a nitric acid solution and transferred to two tanks containing the plating solution. Adequate highly enriched uranium feedstock currently is stored at the LANL site to be capable of supplying a quantity of targets that would meet full production needs for several years.

The solutions from each tank would be transferred to the plating glove boxes. The plating process would pump the solution through a cathode-connected stainless steel target tube. A carbon anode rod would be centered inside the target tube. Plating would require 12 h to 15 h and produce a maximum of 20 g of uranium coating per target. The target plating quantity, quality, and tube integrity would be verified according to LANL quality assurance requirements. The targets would be pyrolyzed, assembled, and welded, and the completed targets leak tested. The Chemistry and Metallurgy Research Facility, Wing 9 target fabrication layout, is shown in Figure 3-5.

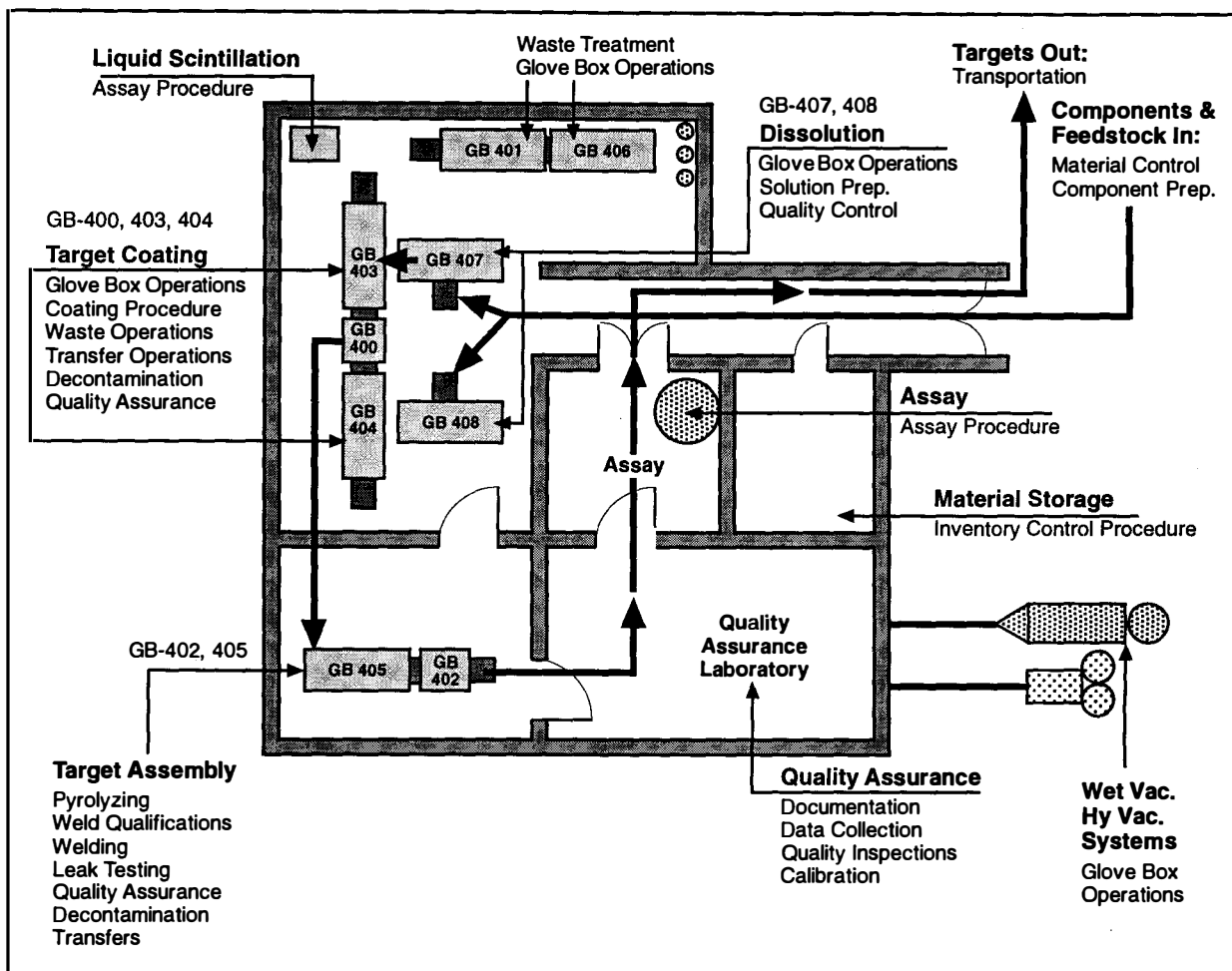
From other initiatives, LANL has significant experience in recovering uranium from solution. Spent plating solution would be recycled in ion exchange glove boxes to recover the unused uranium. Residues from this process would be collected in drums, sampled, and analyzed before transport to the TA-50 Radioactive Liquid Waste Treatment Facility at LANL. The motivation for the uranium recovery is waste minimization, as opposed to economics.

For criticality safety, a limit of 800 g of uranium-235 per glove box has been established. A maximum of 6 kg of uranium-235 is allowed in the entire target fabrication area to maintain the area as a low-hazard category.



SG95110116.48

Figure 3-4. Configuration of Completed Target



SG95110116.51

Figure 3-5. Uranium Target Fabrication Line, Process Flow and Procedures

Target Shipment to SNL/NM. Targets fabricated at LANL would be packaged and shipped to SNL/NM. The packaging would be U.S. Department of Transportation (DOT) approved Type A containers (specifically, BX-22 containers) designed to hold 12 targets each. Shipment of two of the BX-22 containers would supply 24 targets per week. The target supply required would depend on the percentage of U.S. demand for Mo-99 which the Annular Core Research Reactor would be required to fill and on the ability of the Annular Core Research Reactor to develop target power. As many as 35 and as few as 2 targets per week are anticipated to be required. The target packages would comply with DOT regulations for fissile materials delineated in Part 49, Code of Federal Regulations (CFR), Section 173.417.

Targets would be shipped to SNL/NM via NM 4, U.S. 84, and Interstate 25, as depicted in Figure 3-2. Target shipments would occur about once a week. Based on the nature of the Type A packaging proposed for use, each shipment would be limited to less than 500 g (17.5 oz) of uranium-235. Two BX-22 packages of targets with less than 250 g each would be allowed on a single shipment.

As specified in 49 CFR 173.457, the shipments would comply with DOT regulations for the transportation of Fissile Class III packages. Regulation 49 CFR 173.457 (b) (1) and 175.703 (c) (1) states that Fissile Class III packages must be shipped in exclusive-use conveyances. Fissile Class III shipments must incorporate controls designed to ensure

- nuclear criticality safety
- loading, storing, or transporting a shipment of Fissile Class III material with any other fissile material is prevented
- the shipping documents include the descriptions required in 49 CFR 172.203 (d).

Each shipment of unirradiated targets would involve the transportation of less than 500 g total of uranium-235. Under Nuclear Regulatory Commission (NRC) regulations, the material would be classified as Special Nuclear Material of Low Strategic Significance (10 CFR 73.2). Transportation of the target material would be performed under the requirements of 10 CFR 73.67(e). This section of the Code of Federal Regulations specifies the in-transit requirements for special nuclear materials of low strategic significance. The responsibilities of the shipper and receiver and physical protection requirements for the shipment are delineated.

An alternative method for packaging the unirradiated targets would be to use specific Type B containers, such as the DOT Specification 6M container, as specified in 49 CFR 173.417. In this case, 12 targets could be packaged into each container, for a total of 240 g (8.5 oz) of uranium-235 per package. Use of this type of container would qualify the packages of targets to be classified as Fissile Class I packages. It would also remove any criticality-based limit to the number of packages that could be transported in any shipment. The same physical protection measures for the Type A containers, as delineated in 10 CFR 73.67(e), would be required.

The targets would be processed through the normal special nuclear material receiving procedures of SNL/NM. These procedures contain appropriate corrections to the SNL/NM criticality safety and radiological controls procedures. Establishment of a separate receiving area for special nuclear materials, called a material balance area, is planned at Technical Area V for direct receipt of the target shipments. The targets would then be assigned to this material balance area where they would be stored awaiting use in the reactor. A 6-month supply of targets would be stored in Technical Area V. Each target would be identified with a sequential serial number. Special nuclear materials control would include identification of target locations while the targets were in the reactor.

Target Fabrication at SNL/NM. The target fabrication processes also could be implemented at SNL/NM. Because special facilities are not required, the target fabrication area could be located in any of a number of buildings located within Technical Area V without extensive facility modifications. The process described for fabricating targets at the Chemistry and Metallurgy Research Facility, Wing 9, would

be used. Targets would be fabricated and stored onsite until needed for irradiation in the Annular Core Research Reactor, also located in Technical Area V.

The highly enriched uranium needed for target fabrication would be transported from DOE facilities at either Portsmouth, Ohio, or Oak Ridge, Tennessee. This material would be stored at SNL/NM in facilities designated for storage of highly enriched uranium and other special nuclear materials. The wastes from the fabrication process would be low-activity low-level waste which would be transported to the Nevada Test Site for disposal with the other low-level waste produced at SNL/NM.

3.3.1.4 Target Irradiation Activities at the Annular Core Research Reactor

The Annular Core Research Reactor is located in Technical Area V at SNL/NM. The facility consists of the reactor and all support systems required for its operation and conduct of experiments. A sketch of the Annular Core Research Reactor floor plan is shown in Figure 3-6. The Annular Core Research Reactor is a pool type research reactor capable of steady state, pulse, and tailored transient operation. It became operational in 1978 and was originally designed with characteristics suitable to support electronics testing and reactor safety research programs. The Annular Core Research Reactor is currently operational. The current Annular Core Research Reactor configuration consists of an annular (thick cylindrical or flat doughnut) array of 236 highly enriched uranium beryllium oxide-fueled elements with an active fuel length of 52 cm (20.5 in). This fuel would be used for initial Mo-99 production. However, the reactor would be transitioned to a completely low enriched uranium-fueled core as the highly enriched uranium fuel reaches a 5% burnup limit (approximately 10 months at a reactor power of 3 MW).

- | The reactor core is installed in a large open tank filled to a depth of approximately 10 m (33 ft)
- | containing about 49 m³ (1730 ft³) of water to provide core cooling and radiation shielding. It has a central

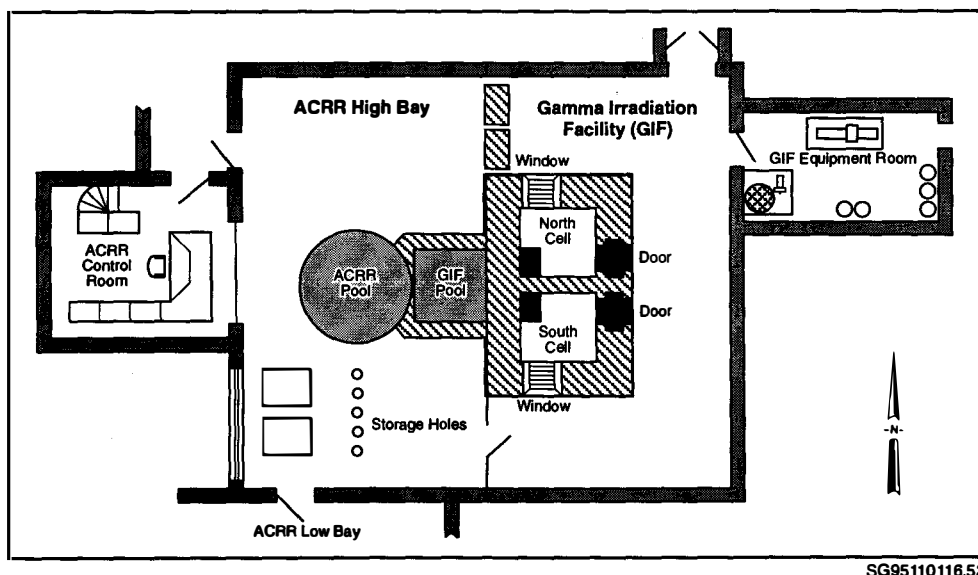


Figure 3-6. Annular Core Research Reactor Floor Plan

thermal flux region that configures 19 targets for irradiation in a partial production mode and 37 targets in a full production mode. The core is cooled by natural convection. The water pool is cooled by an external heat exchanger. Currently, the Annular Core Research Reactor is limited to operation at, or below, 2 MW in the steady state mode, due to the current cooling capability of the Annular Core Research Reactor pool water.

The core configuration would be changed for the isotope production program. The Annular Core Research Reactor would be operated exclusively in the steady-state mode with the reactor power cooling capability increased to 4 MW. The modified core would initially contain 170 highly enriched uranium beryllium oxide fuel elements. After the transition is complete, the core will be fueled with 190 low enriched uranium Training, Research, Isotope Production, General Atomics (TRIGA) type fuel elements with no zirconium hydride added. The fuel, without this compound added, would not acquire the inherent dynamic safety characteristics of a TRIGA reactor, but would generally retain the dynamic safety characteristics currently possessed by the Annular Core Research Reactor. TRIGA fuel with zirconium hydride has a very powerful prompt temperature coefficient that rapidly turns power transients. The current Annular Core Research Reactor dynamic characteristics have been used in the Annular Core Research Reactor safety analysis, which is acceptable for reactor operation. A modified central region, about 22.8 cm (9.0 in.) in diameter, would be used for irradiation of targets. A description of the proposed modifications to the Annular Core Research Reactor is contained in Section 3.3.1.9.

During irradiation, each target would generate a power level of approximately 20 kW at partial production levels and 15 kW at full production levels. This difference is due to the configuration required to produce an aggregate target power of approximately 490 kW. For a discussion of target power level and why it is important, see Appendix A.

The open pool reactor design would allow ready access for insertion and removal of the targets and fuel elements. Irradiated targets would be removed from the core and transferred via the pass-through ports to a rack in the Gamma Irradiation Facility pool.

3.3.1.5 Target Transfer to Hot Cell Facility

A transfer cask capable of supplying the required shielding for four 21-kW targets would be lowered into the adjacent Gamma Irradiation Facility pool. During initial operation, a single 21-kW target would be loaded and transferred to the Hot Cell Facility. After the new hot cell is completed, up to four irradiated 21-kW target(s) would be loaded into the cask for transfer to the Hot Cell Facility. The cask would then be removed from the pool using the bridge crane, surveyed for contamination, and moved, using a manned transport vehicle. The cask would not be sealed but would be closed. The distance between the reactor and the hot cell facilities is only a few hundred feet and does not require a sealed cask.

A manned transport vehicle would be used to move the targets out of the reactor room and into the adjacent Hot Cell Facility. The transporter would exit the reactor facility through the proposed airlock, which would permit the continued operation of the reactor, and proceed down the ramp to the Hot Cell

Facility (see Figure 3-7). The transporter would enter the Hot Cell Facility through the roll-up door at the west end and then proceed to the Hot Cell Facility transporter airlock.

When through the airlock, the cask would be moved to the far north end of the Hot Cell Facility, where it would be placed within the shielded region to be designated Zone 2B. This zone would consist of a long central room within the Hot Cell Facility with remote manipulators and lead-glass windows. The cask would then be moved below one of the dedicated processing boxes designed to conduct the initial steps of the isotope extraction process. When empty of targets, the transfer cask would be removed from Zone 2B and returned to the reactor facility to await the next movement of targets.

The movement of targets from the Annular Core Research Reactor room to the Hot Cell Facility would be conducted up to 3 times a day, 5 days a week, and 52 weeks a year. The number of targets transported would depend upon the required production rate and the individual target power that can be achieved after the Annular Core Research Reactor is reconfigured. Approximately 20% of the weekly demand could be produced by processing one 20-kW target a day for 5 days, and 100% could be produced from seven 15-kW targets a day for 5 days.

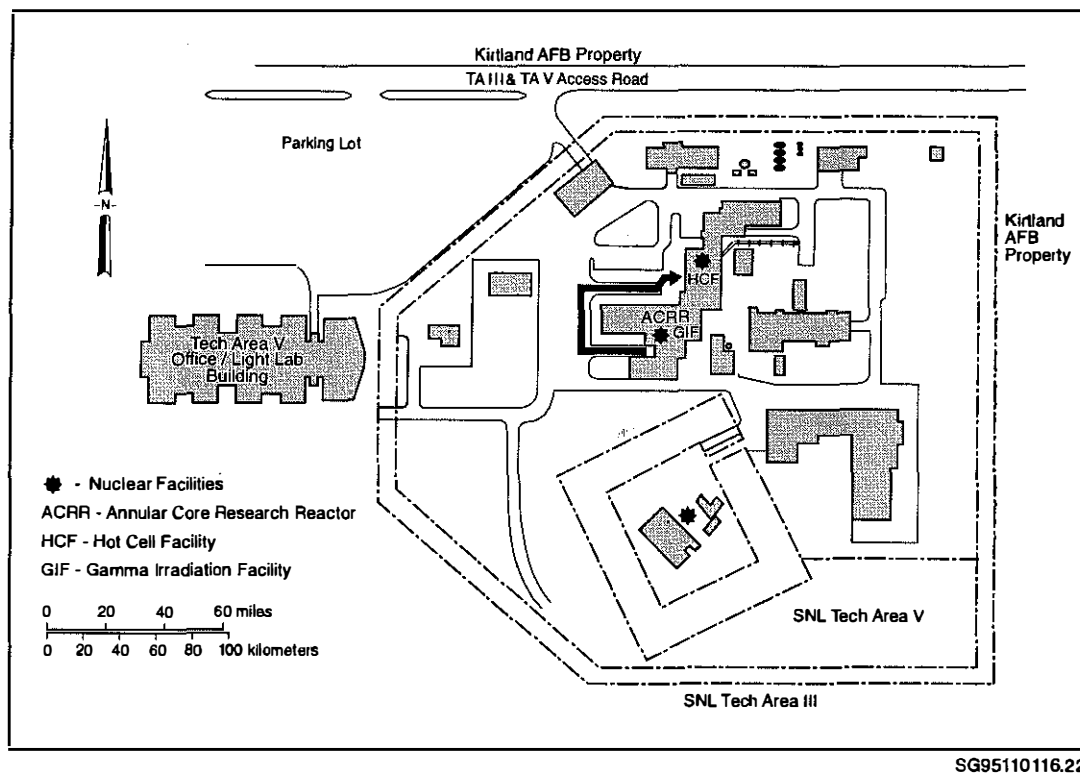


Figure 3-7. SNL/NM Technical Area V Complex

3.3.1.6 Isotope Extraction at Hot Cell Facility

The existing hot cell facility at SNL/NM would be used for the initial testing and initial processing at up to 10% production. However, because it was not designed for routine chemical processing or fission product recovery (Massey et al. 1995), it would not be adequate for conducting the full production Mo-99 mission (see Figure 3-8).

The cell wall of the existing hot cell is 106.7 cm (42 in.) thick with a concrete density of 2.35 g per cm^3 . Approximately 2000 Ci of 1 MeV gamma photons at the wall of the cell would result in a dose rate of 1 mR/h at the surface of the cell wall. The hot cell is actually a single bay with five window and manipulator stations. The bay is segregated into three process boxes. Two process boxes contain two process stations, consisting of a window and a set of manipulator stations. The third box contains a single station. A spill in one of the boxes could impact other activities in the same box at an adjacent station, but not in an adjacent process box.

A second hot cell bay of five window and manipulator stations would be constructed in the same facility to accommodate full production of Mo-99. This new cell and stations would be adequate for a full Mo-99 production mission (greater than 100,000 Ci at 1 MeV would produce a dose rate of 1 mR/h at the surface of the cell wall). This set of cells would be segregated from one another by process boxes, effectively disposing of the potential spill problem with the existing cell (see Figure 3-9).

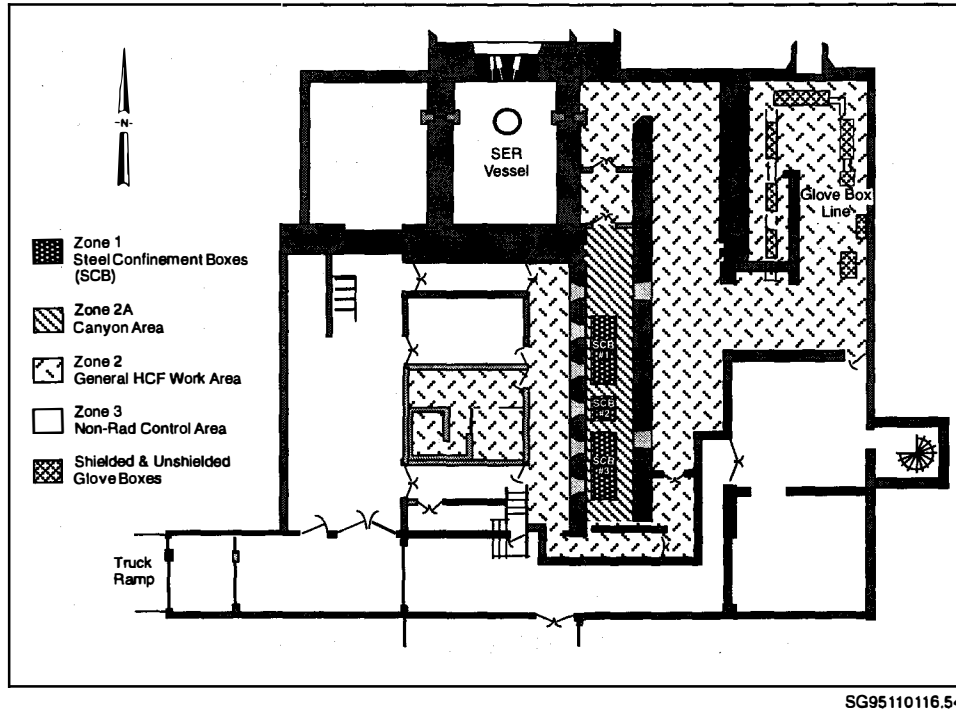


Figure 3-8. Current Hot Cell Configuration

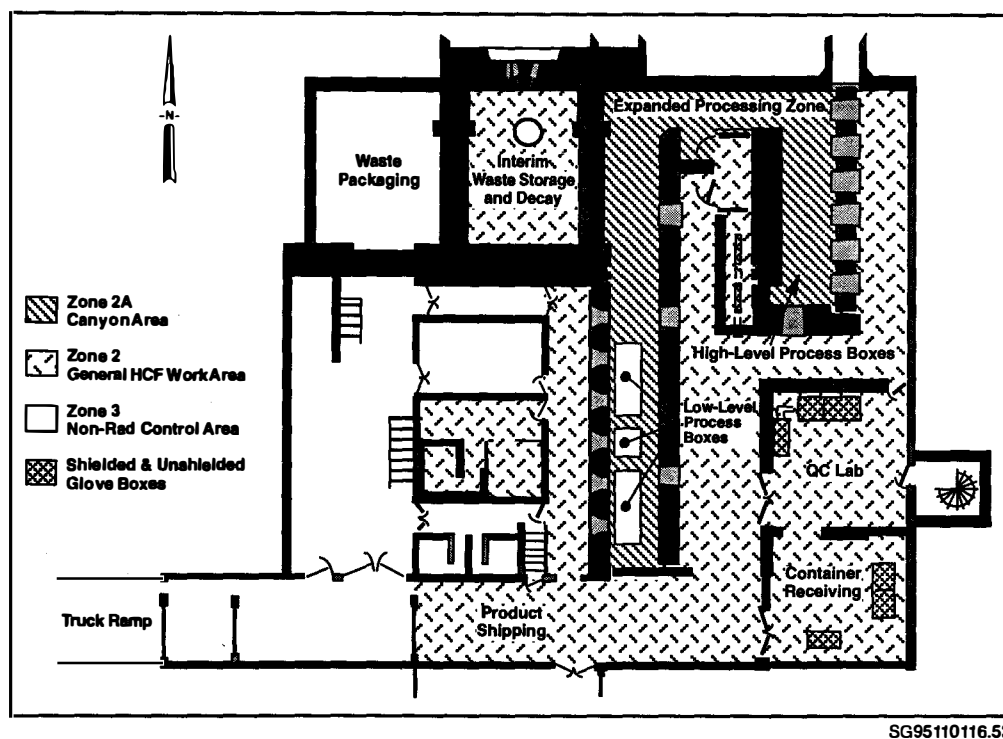


Figure 3-9. Hot Cell Configuration for Full Isotope Production

Routine production of up to 10% of the U.S. demand would require additional shielding in the hot cells to minimize the worker dose. Should greater than 10% production be necessary prior to the completion of construction of the new hot cell facility, it could be achieved with a proportionate increase in person-rem exposure to the hot cell operators. This production increase could be successfully accomplished without exceeding as low as reasonably achievable (ALARA) limits by increasing the number of trained hot cell operators or through careful dose management.

The irradiated targets would be opened in the hot cell, and noble gases and iodine would be condensed from the target fill gas. The liquid from the target dissolution would be drained into a bottle, treated to precipitate elemental iodine, and filtered to remove silver iodide. Molybdenum carrier (sodium hydroxide) would be added to the remaining solution. After several more steps of washing and removing impurities, including ruthenium, rhodium, and organic residues, the resulting product solution would contain sodium molybdate in dilute sodium hydroxide. Approximately 1200 to 1400 mCi/mL of Mo-99 would be expected per target. Immediately after irradiation, each 21 kW target would contain approximately 850 Ci of Mo-99.

After completing the procedure for the purification of Mo-99, the product would be tested by gamma spectroscopic analysis. Such analysis would be useful not only in determining the nature of contamination, but in enabling the quality control laboratory to quantify the impurities and the Mo-99 content. This information would be used to prepare the Material Safety Data Sheets that accompany the shipment.

The extraction process also would provide radioisotopes of xenon and iodine. Based on an irradiation power of 21 kW per target, each target could yield approximately 600 Ci of Mo-99, 200 Ci of iodine-131, and 600 Ci of xenon-133 one day after discharge from the reactor. A 15-kW target would reduce these contents linearly.

3.3.1.7 Product Shipment

The Mo-99 would be packaged in Type B accident-resistant packaging for shipment to the radio-pharmaceutical companies. Air express class of shipments would be used with direct routing, if possible, to the customer city. Passenger carrying aircraft could be used, as the Transport Index (a federal requirement discussed in 49 CFR 175, basically specifying the dose rate from a radioactive shipment measured at 1 meter from the package surface) of the Mo-99 package is within the limit allowed on passenger aircraft. Based on consultation with KAFB, product movement would be direct from Technical Area V to the airport transfer point, using KAFB access roads.

3.3.1.8 Waste and Spent Nuclear Fuel Management

Nonhazardous chemical waste, low-level solid and liquid radioactive waste, and spent nuclear fuel would be generated at SNL/NM as a result of the medical isotope production program. The solid waste generated would consist primarily of office trash and laboratory trash. Some chemical nonhazardous waste from process verification activities or from expired, contaminated, or otherwise unusable chemicals would also be generated. This solid waste and chemical waste would be handled through the established waste management processes at SNL/NM in accordance with all applicable federal, state, local, DOE, and SNL/NM requirements. Incidental mixed wastes may be generated, such as batteries and solvent cloths, which would be handled under standard SNL/NM waste management procedures. Approximately 56.3 m³ of low-level waste would be generated per year from Mo-99 production activities at 100% of U.S. demand. Waste would be stored in the Hot Cell Facility for approximately 6 months to allow decay of short-lived radionuclides. The low-level waste would be shipped to the Nevada Test Site. The description of waste treatment and disposal is based on current practice and may change based on future decisions resulting from the DOE waste management study (1995a). Spent nuclear fuel would be stored in the Gamma Irradiation Facility pool pending a decision on its final disposition in accordance with the SNF PEIS (DOE 1995b).

SNL/NM estimates that, at a production rate of 80% of the U.S. demand, sufficient storage exists within the Hot Cell Facility to allow up to 2 years storage of waste generated (based on processing approximately 19 targets per week). At 100% production levels, approximately 34 targets at 15 kW would be required per the assumptions in Appendix A, which would reduce storage space to about one year's worth of waste.

3.3.1.9 Required Modifications

Some modification of existing facilities/operations would be required to implement the medical isotope production program. The following sections provide a description of these proposed modifications.

Chemistry and Metallurgy Research Facility Modifications at LANL. The changes required for the target fabrication operations in the Chemistry and Metallurgy Research Facility, Wing 9, are relatively minor. Some changes, which are in support of the target fabrication process validation activities (applicable to all alternatives), are ongoing.

In addition, some interior walls would be removed and doors would be relocated to form a single-point access suite of five rooms. Nine glove boxes would be custom fabricated to contain the apparatus for the process steps as two parallel, duplicate production lines. Each glove box exhaust would be fitted with a HEPA filter. Apparatus in glove boxes would include the following:

- dissolution tanks
- introduction boxes
- target coating lines
- quality assurance and assay equipment
- decontamination equipment
- ion exchange system
- storage tanks
- leak testing equipment
- pyrolyzing and welding equipment.

Additional exhaust ducting and fans would connect the glove box ventilation systems to the existing Chemistry and Metallurgy Research, Wing 9 ventilation system.

Annular Core Research Reactor Modifications at SNL/NM. The past missions of the Annular Core Research Reactor have required intermittent operations in both a power pulse mode and a steady state mode. The isotope production program would require continuous operation in steady state mode at 2 to 4 MW. The power pulse mode, an operational mode where a large power pulse generates a large number of fast neutrons for brief periods, is not needed for the Mo-99 production mission, but capability to operate in such a mode must be retained in order to support potential future defense needs. The pulse mode is required for the conduct of nuclear weapons research. Increasing the Annular Core Research Reactor continuous operational power level to 4 MW would require upgrades to the reactor cooling system to include additional redundant heat exchanger units and a cooling tower. The Annular Core Research Reactor tank has provisions that allow for use of a forced cooling system: however, this feature has never been used and operations at 4 MW are not expected to require the use of a forced cooling system.

In addition, the present fuel is a highly specialized design. A replacement fuel would have to be installed so the present fuel would not become highly exposed by the Mo-99 production activities. DOE

has conducted extensive numerical modeling efforts to predict the reactor power and flux characteristics using various replacement fuels and core configurations. Calculations by DOE indicate the target irradiation level needed to meet U.S. demand for Mo-99 could be achieved with relatively minor modifications to the Annular Core Research Reactor core. Two different target/core configurations could produce 20% to 100% share of the U.S. market. Based on calculations, fuel availability, and cost, DOE proposes to use a low enriched uranium TRIGA-like fuel composed of uranium zirconium. This fuel would have the dimensions of standard TRIGA fuel, but would contain no zirconium hydride.

Expansion to meet a slightly greater than full demand could be performed by increasing the power level to 4 MW, utilizing the central irradiation facility in a 37-target gridplate design, and irradiating each target at a power level of 15 kW. The 37-target design would be required for >80% production.

After the Annular Core Research Reactor is reconfigured and the replacement fuel installed, testing would be performed to determine the number of targets required and the actual target fuel configuration to be deployed to meet the U.S. demand. The Safety Analysis Report and Technical Safety Requirements, which have been updated to meet current DOE Order requirements and to reflect the upgrade to 4MW, would also be modified to reflect the new fuel and reconfigured core. The number of targets that would have to be irradiated to meet the U.S. demand for Mo-99 would affect the amount of waste generated by the production process.

Additional modifications that would be required to successfully conduct the Mo-99 production mission follow:

Procurement/Installation of Heat Exchangers and Cooling Towers - The current steady state power limit for the Annular Core Research Reactor is 2 MW. This limit is due to the combined heat rejection limitations of the heat exchanger/cooling tower system. DOE calculations indicate the installation of additional heat exchanger and cooling tower heat rejection capacity (two towers, 4 m x 4 m x 3 m) would allow the reactor to run at 4 MW and maintain a pool water temperature of 40°C (104°F) for desired performance of the reactor and the pool water treatment system.

Removal of Central Cavity Liner Tube - The central cavity was used in past operations to provide a dry, high neutron flux location in the core. Removal of the central cavity liner tube would flood this area of the core and allow targets to be placed there for irradiation. Removal of the central cavity liner tube for isotope production also has the benefit of reducing argon-41 production and its subsequent release to the environment.

Hardware Upgrades and Redundancy - Because the Mo-99 production program would require continuous operation, redundancy features would be required to increase and sustain the performance of the Annular Core Research Reactor. Redundancy features include reactor control subsystems and rod drives. All upgrades and redundancy modifications would retain the objective of reliable and continuous operation. Minimizing personnel radiation exposure is a driving consideration for these upgrades.

Removal of Extraneous Hardware - Extraneous hardware would be removed from the Annular Core Research Reactor or core tank in order to make the reactor as flexible as possible for isotope production. The extraneous hardware includes the central cavity, a neutron radiography tube, and external cavities.

Ventilation and Environmental Monitoring Upgrade and Redundancy - The ventilation and radiation monitoring systems would be upgraded for continuous operation and redundancy.

Special Handling Equipment - Fuel racks, transfer casks, and target handling equipment would be designed or purchased to meet isotope production needs. Some of these items would be fabricated in the Area I Machine Shops. Other items would be fabricated at a local commercial machine shop.

Air Lock Addition - Operation of the Annular Core Research Reactor currently does not require use of an air lock. For the proposed action, however, delivery or removal of materials without an air lock would require shutdown of the reactor in order to minimize the potential for airborne emissions. Therefore, an air lock would be installed, so that a negative pressure differential relative to the atmosphere could be maintained in the Annular Core Research Reactor highbay. Materials could then be transferred into and out of the Annular Core Research Reactor with a minimum of shutdown time. Installation of the airlock would require construction of a small (3.65 m by 3.65 m [about 12 ft by 12 ft]) addition to the building to enclose the airlock space.

Backup Electrical Power - To minimize interruptions of and to ensure continuous production operations, backup electrical power may be needed. Backup power is not a safety requirement. Backup electrical power could be provided by a diesel generator purchased and installed in Technical Area V.

Material Balance Area - A new material balance area would be established at Technical Area V to specifically handle the receipt of targets. Such a change would be primarily an administrative procedure and would require minimal modification of an existing facility.

Hot Cell Facility Modifications. By simply adding more shielding, the existing hot cell would be capable of producing approximately 10% of the current U.S. demand for Mo-99. However, routine production activities, at a target processing rate greater than 10% of the U.S. demand for Mo-99, would not be practical (refer to Figure 3-8).

To meet greater than 10% of the U.S. demand for Mo-99, a new hot cell with five sets of lead-glass windows and manipulators (Zone 2B) would be constructed in the existing hot cell facility. These stations would be physically separated inside the cell by means of process boxes. The new hot cell in Zone 2R would be located in the Hot Cell Facility adjacent to the existing hot cell in Zone 2A (refer to Figure 3.9). The new hot cell would be designed to handle a total content of 100,000 Ci of 1 MeV gamma-emitting radionuclides. Zone 2B would be designed to achieve the SNL/NM ALARA goal of 500 mrem/yr for an individual. While the new hot cell was being constructed, the existing hot cell would be used for process validation and FDA certification testing. By performing these activities in parallel with the construction of

the new hot cell, the time required to begin Mo-99 production activities would be minimized. In addition, the existing hot cell would be used for Mo-99 purification activities that do not involve handling high activity materials.

Activities that are under way include removal of legacy radioactive materials from the existing hot cells, removal/relocation of several interior walls, and completion of the control console upgrades that have been under way for several years.

Hot Cell Facility Ventilation Upgrade - A major upgrade to the ventilation system for the existing hot cell would be necessary for handling potentially acidic atmospheres within the hot cell during the Mo-99 extraction process. The upgrade would also allow for the handling of an iodine release incident without the shutdown of the Mo-99 extraction process. Series-parallel arrangements of charcoal filtration units would allow one unit to hold up an iodine release and maintain hot cell operation by switching to the second unit.

Mo-99 Process Line Installation - Processing equipment unique to isotope production would have to be procured and installed prior to production. Examples include extraction process equipment and waste processing equipment.

Quality Control Laboratory - This laboratory would be required by the approved FDA procedure. The Quality Control Laboratory requires a minimal amount of space and equipment, such as ventilated shielded glove boxes and detection equipment. Additionally, small shielding enclosures would be installed around selected equipment. Floor space in the Hot Cell Facility has been identified and no significant construction is anticipated for this laboratory.

Reconfiguration of Hot Cell Facility to Streamline Process - Modifications to the east wall, entry door location, and internal overhead crane would be required. Wall modifications would involve providing cutouts for additional manipulators, lead-glass windows, and a pass-through. Moving the entry doors would produce more available space, thus minimizing crowding and facilitating remote replacement of containment boxes. Overhead handling equipment modifications would facilitate movement of materials, supplies, and containment boxes.

Steel Containment Boxes - Proposed replacement steel containment boxes would result in safer, more reliable, and more versatile hot cell operations to service isotope production. The new steel containment boxes would be designed to provide complete process control, including waste minimization and management. The boxes would also allow collection of by-products from the radioisotope extraction, processing the by-products, and packaging them into waste containers. The design of the steel containment boxes would be modular to allow easy replacement of components. Replacement of steel containment boxes would require the removal of existing steel containment boxes or interior walls.

Waste Storage Area - Existing rooms would be modified to efficiently manage waste from the process line. Minimal upgrades to the current area would be required. Installation of floor railing or motorized remotely operated moving equipment is anticipated.

Process Validation Testing. Prior to production, some activity would be devoted to reactor physics experiments and process design activities. Such activities would require the procurement of some equipment or hardware. These activities are characterized as *proof-of-principle* studies that would support design and operational activities related to medical isotope production.

- **Process Design** - One or more prototype steel containment boxes and prototype processing equipment would be set up for examination of equipment performance, reliability, and adequacy of design.
- **Reactor Physics Experiments** - The existing calculations for isotope production in the Annular Core Research Reactor would be verified by irradiating targets in the Annular Core Research Reactor after the conversion to continuous operation is complete. This process would help determine configurations, reactor power, reactor operations, and the number of targets required to meet the U.S. demand for Mo-99.
- **Prototype Target Fabrication** - Test targets would be fabricated and tested to verify processes.

Conversion of Annular Core Research Reactor to Support Defense Program Mission. If the Annular Core Research Reactor is transferred to the DOE Office of Nuclear Energy, Science and Technology, then the Office of Defense Programs would retain the right for the Annular Core Research Reactor to be available to support defense missions in times of national emergency to address security concerns. Under such an arrangement, the Annular Core Research Reactor must be made available, if required. Consequently, the proposed action would involve maintaining capabilities within the Annular Core Research Reactor to return to its current defense mission, operating under conditions similar to the ones that presently exist. It is possible that the Annular Core Research Reactor (ACRR) could be diverted to support defense missions in case of a national emergency. However, the Department has determined that the probability of needing the ACRR for defense purposes is sufficiently low to preclude disqualifying the reactor from consideration. The ability to convert the Annular Core Research Reactor to defense activities requires retaining the capability for a pulse-mode operation, the capability to install the irradiation cavity liner tube, and access to a steel containment box to support defense activities. The modifications required for the proposed action do not eliminate the possibility of returning the facilities to support national security requirements.

The Annular Core Research Reactor is currently fueled with beryllium oxide fuel elements that were developed specifically for Defense Program testing and are irreplaceable. As a result, the fuel currently in the Annular Core Research Reactor would be systematically replaced and stored onsite (in the Gamma Irradiation Facility pool) for possible use in the future. The plan is to use transition cores of beryllium

oxide fuel, normal TRIGA fuel, and TRIGA fuel with no zirconium hydride. The final configuration would be a core of TRIGA fuel with no zirconium hydride, surrounded by a reflector blanket of normal TRIGA fuel.

The current Annular Core Research Reactor core has 236 fuel elements of a beryllium oxide highly enriched uranium design that are approximately 75 cm (29 in.) long and 3.8 cm (1.5 in.) in diameter. These fuel elements are of a specialized design that can be used for both steady-state and pulsed operation. The proposed isotope production program does not need the pulse-mode operational capability. A replacement low enriched uranium fuel element design (not containing beryllium oxide) suitable for steady state operation would be used. Current plans call for the removal and storage of the current fuel elements so that they would be usable later for pulse-mode operation. The current core of fuel elements could be used for a brief duration at full production levels and still be usable for pulse mode operation to meet potential defense needs. The total depletion target for removal of these beryllium oxide elements is less than 5% depletion. The fuel element lifetime for both the beryllium oxide elements and the TRIGA elements would depend primarily on the amount of Mo-99 production required.

To ensure the Annular Core Research Reactor could be quickly reconfigured for pulse testing of nuclear weapons components in an emergency related to maintaining the nuclear stockpile, much of the hardware currently in the Annular Core Research Reactor pool would be stored in a configuration that would guarantee its long-term integrity and usability. The proposed storage area for hardware would be a new tank accessible by overhead crane. This equipment storage tank would be installed in the south part of the Annular Core Research Reactor building. The hardware stored in the equipment storage tank would include only nonfuel components required for this activity, such as the fuel-ringed external cavities (FREC-I and FREC-II) without the fuel, control elements and drives, support hardware, the central cavity liner tube, and the radiography system. The equipment storage tank would only be used for storage. No ongoing or sporadic operations involving movement of materials into or out of the tank would occur, unless the decision were made to move the stored hardware back into the Annular Core Research Reactor to support a defense mission in a national emergency.

The proposed equipment storage tank would not be designed or equipped for future operation as a reactor or weapons research facility. No major electrical connections or conduits, no cooling systems, and no mechanical service ports would be installed or allowed in the design. Only those items necessary for safely maintaining the hardware would be installed. These items would include a water treatment system for maintaining clean water in the tank used for radiation shielding, and the fittings for lights and leak sensors.

The FREC-II tube is approximately 7.6 m (25 ft) in length. The tube must be stored vertically to prevent distortion that would destroy the precision tooling of the tube, which was designed for precise radiation streaming control. The proposed equipment storage tank would be designed to allow vertical storage of the hardware. The tank would be sized only for storage of Annular Core Research Reactor defense-related hardware. The final size and shape of the equipment storage tank would be based on cost

and hardware integrity needs. During inspections of the hardware in storage, the water in the tank would shield personnel from the radiation emitted by the activated hardware.

The construction and installation of the equipment storage tank would include the following:

- Relocation of the existing cavity purge system from the Building 6588 lowbay to the high bay roof.
- Extension of the 5.5 m (18 ft) wide by 15 m (50 ft) long penthouse a distance of 9 m (30 ft) to the south.
- Installation of a double-walled steel storage tank of approximately 13.5 m² (145 ft²) surface area by 10.7 m (35 ft) deep in the low bay.
- Provision for maintaining water quality suitable for storage of equipment in the storage tank.
- Upgrading the heating, ventilation, and air-conditioning (HVAC), power, and lighting, as needed for the storage area.
- Relocating utilities and removing a portion of the wall between the existing high bay and the new high bay extension.

Constructing the equipment storage tank would not affect the operation or schedule for medical isotope production activities at SNL/NM. No radioactive material would be released to the atmosphere from the equipment storage tank.

3.3.1.10 Estimated Schedule for Modification

The SNL/NM has developed a detailed schedule for the modifications planned at the LANL and SNL/NM facilities. The proposed schedule was updated through July 1995. Initial Mo-99 production for FDA testing and certification could begin as early as 6 months from the date of the Record of Decision. The estimated date for completion of all construction and testing activities for Mo-99 production is 22 months from the date of the Record of Decision. Full production capability would follow at 28 months from the date of the Record of Decision.

3.3.2 Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

The LANL was established in 1943 to design, develop, and test nuclear weapons. The LANL is operated by the University of California and supports research projects in nuclear physics, hydrodynamics, conventional explosives, chemistry, metallurgy, radiochemistry, and biology. In 1992, LANL expanded its mission to include development of programs in health and biotechnology, environmental technologies, and

industrial partnerships. The LANL is located on 111 km² (43 mi²) of land in Los Alamos County in north central New Mexico, approximately 96.6 km (60 mi) north of Albuquerque, and 40.25 km (25 mi) northwest of Santa Fe.

The LANL has successfully produced and marketed radioisotopes for 50 years and has successfully produced and marketed medical radioisotopes for more than 20 years. LANL has a current ongoing program established in the medical radioisotope field. LANL received the FDA official certification of Drug Establishment in August 1991 (FDA 1995).

In response to the shutdown of the Cintichem reactor, LANL was identified, in late 1991, as the proposed site to provide a backup supply of Mo-99 to the medical community in the U.S., in response to the shutdown of the Cintichem reactor.

In December 1992, the Omega West Reactor experienced an unplanned reactor shutdown. In January 1993, during the shutdown, a leak from the primary cooling system was identified. The leak had occurred in the 76-cm (30-in.) delay line shown in Figure 3-10. This leak occurred as a result of organic attack on the outside of the line due to high sulfur content in the soil. DOE (1995c), Andrade (1995), and Peterson (1995) provide additional details relative to the Omega West Reactor shutdown.

Investigations have shown that the leaking pipe could be repaired without impairing the operating characteristics of the reactor. The details of the required remediation efforts are described in Section 3.3.2.9.

In 1993, no current or future programmatic need for the Omega West Reactor was identified and action was initiated to place it in safe shutdown. To preserve the Omega West Reactor for a potential Mo-99 mission, LANL has terminated its ongoing decontamination and decommissioning activities at the

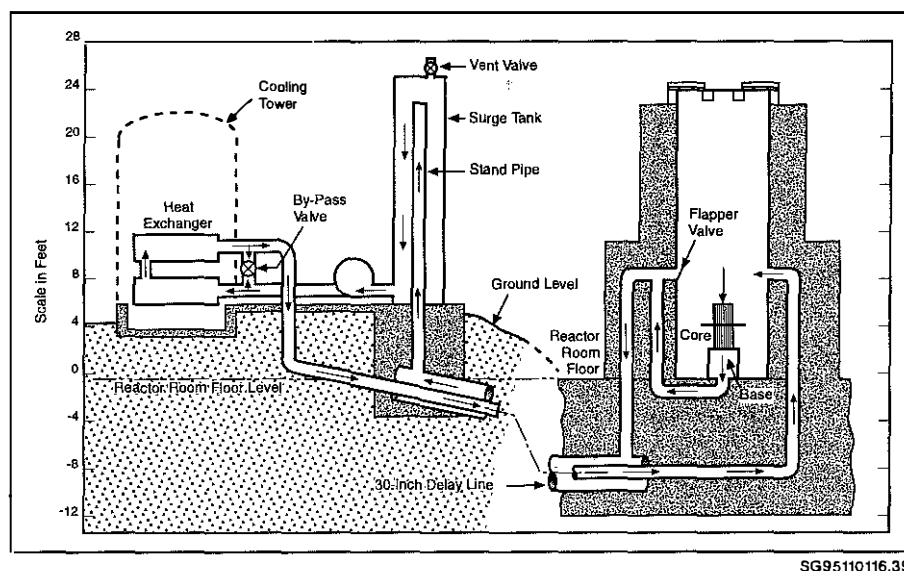


Figure 3-10. Core Cooling System for the Omega West Reactor

facility. LANL has completed some of the required activities that would precede a Mo-99 mission, such as completion of drafts of the licensing basis and draft Safety Analysis Report (SAR), and constructing a stringer assembly.

A restart of the Omega West Reactor faces the challenge of assessing reactor startup related activities. The schedule and the associated cost to deploy the LANL alternative would be influenced by the DOE requirements for the Omega West Reactor restart under DOE Order 425.1 (DOE 1995d). The requirements, which may require a few months to document, would not necessarily preclude a timely restart of the Omega West Reactor.

3.3.2.1 Description of the Alternative

The proposed method to produce Mo-99 at LANL entails the four basic steps of the Cintichem process. Each of the four steps would be conducted onsite at LANL. Wing 9 of the Chemistry and Metallurgy Research building in TA-3 would be used for manufacturing the targets and recovering the Mo-99 in the hot cells. The target irradiation would occur in the Omega West Reactor.

LANL would conduct the program in two phases. During the initial phase, four in-core positions would be dedicated to Mo-99 production, allowing 16 targets to be irradiated. In the second phase, LANL would reconfigure the core to accommodate seven in-core positions and two reflector positions. This reconfiguration would provide irradiation facilities for 36 targets. Mo-99 produced at LANL would be distributed and shipped to radiopharmaceutical manufacturers via commercial carriers using either the Los Alamos Airport, Santa Fe Airport, or the Albuquerque International Airport.

Adequate facilities exist at the site to handle, manage, and store all types of wastes generated during the Mo-99 production. The LANL plans to recycle the uranium that remains in the process waste stream. Low-level waste management at the LANL facilities is a *cradle-to-grave* process, where low-level waste is disposed onsite and no shipment of waste is required.

3.3.2.2 Existing Facilities

Existing facilities at LANL would provide the capability to conduct the four fundamental Mo-99 production operations. The Omega West Reactor would be repaired and restarted to irradiate Mo-99 production targets. The Chemistry and Metallurgy Research Facility would require minor modifications to conduct target fabrication and processing. Radioactive wastes would be disposed onsite. A description of each activity follows.

3.3.2.3 Target Fabrication

Target fabrication in the Chemistry and Metallurgy Research Facility, Wing 9 target fabrication area was previously described in Section 3.3.1.3.

3.3.2.4 Target Irradiation Activities

The targets fabricated in the Chemistry and Metallurgy Research Facility, Wing 9, would be transported in a DOT-approved container (BX-22) to the Omega West Reactor. The roads over which the transport would be conducted are controlled by LANL and could be closed to traffic if required. LANL possesses several BX-22 containers.

The Omega West Reactor, located at TA-2, is a thermal, heterogeneous, covered tank-type test and research reactor. The reactor is light-water moderated and cooled (Figure 3-11). Until it was shutdown in 1992, the Omega West Reactor had been operated by LANL since 1956 without an accident or major operational incident. It had provided 36 years of continuous experimental service with a forced outage rate of less than 2%.

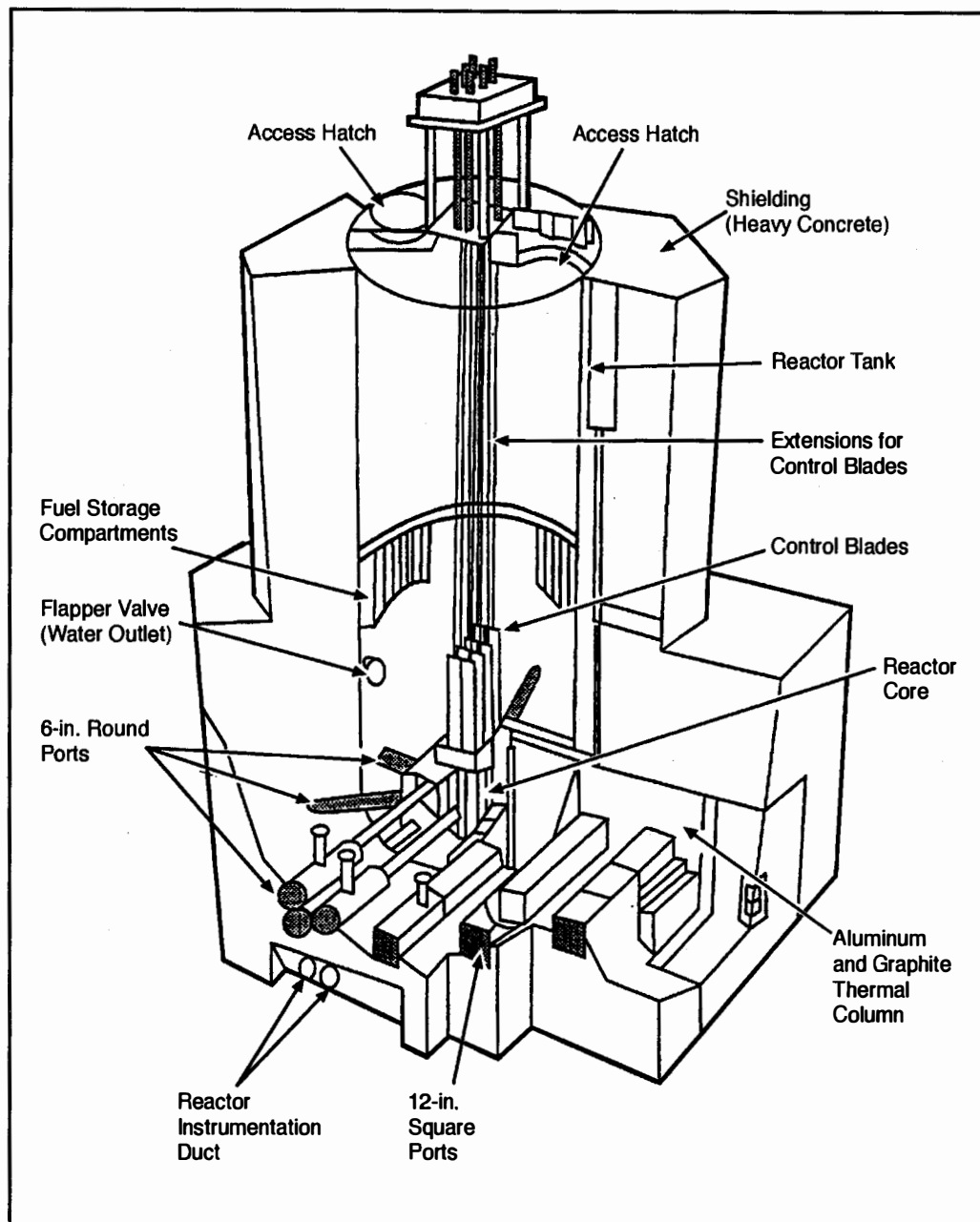
The Omega West Reactor is very similar to the Cintichem reactor, the commercial U.S. reactor that had been producing Mo-99 prior to 1989

- Both designs use Materials Test Reactor plate type fuel and are water moderated and cooled
- Cooling for both designs is by forced circulation
- The irradiation stringers of both designs are nearly identical in all dimensions
- The concept of replacing a fuel element with a target stringer is the same for both designs
- The similarity of the Omega West Reactor to the Cintichem Reactor would reduce technical uncertainties in the transfer of the Cintichem target irradiation technology.

During its early years, the Omega West Reactor was operated at a power level of 5 MW. After facility upgrades during the 1960s, including the construction of a large cooling tower, the Omega West Reactor gained the capability to operate at 8 MW. The peak thermal flux that can be achieved in the Omega West Reactor at 8 MW is approximately 1.0×10^{14} n/cm²-sec. Until 1971, the Omega West Reactor was operated 24 h/day, 5 days/week at the 8-MW level.

The Omega West Reactor would be fueled with Materials Test Reactor type fuel elements containing highly enriched uranium. At full power, approximately 29 fuel elements per year would be discharged from the reactor as spent fuel. The active portion of each element is about 0.625 m (2 ft) in length. The overall length of each element, including the aluminum end caps, is 1.1 m (3.6 ft).

The Omega West Reactor would initiate Mo-99 production using the currently existing highly enriched uranium fuel. After depletion of the current supply, the reactor would be transitioned to use low enriched uranium fuel. Currently, the Omega West Reactor highly enriched uranium fuel in storage is sufficient to conduct the Mo-99 production operation for at least 7 years. Calculations at other facilities



SG95110116.49

Figure 3-11. Cutaway Illustration of the Omega West Reactor

have been performed to support the use of low enriched uranium fuel of similar design. Because this conversion of Materials Test Reactor type fuel has been completed successfully several times without degrading the flux (for example, at the University of Michigan), this conversion would not present a technical challenge.

Approximately 16 targets per week would be irradiated in the Omega West Reactor under the current core configuration. Four targets would be placed into a stringer assembly (Figure 3-12). The stringer assembly body design is virtually identical to the one used at the Cintichem Reactor. To permit insertion into the Omega West Reactor grid plate, different nose caps would be required. Each stringer would be designed to fit in locations previously occupied or designed for fuel elements. The stringers allow primary coolant to flow down the stringer and around the target cylinders. Stringers are interchangeable with fuel elements, but can only be used in positions for which core configuration calculations have been performed. Each target marginally impacts the reactivity of the core. This nearly neutral reactivity is due to the parasitic absorption of the stainless steel target cylinders balancing the production from the fission rate of the target fuel.

Each target stringer would be irradiated at a target power of approximately 20 kW for approximately 7 days. The irradiated target would be removed from the reactor and allowed to cool for 6 h in the fuel storage bins located on a shelf on the inside wall of the reactor. A basket would be installed around the storage shelf to prevent targets from falling onto the core.

The stringer would be removed from the reactor vessel with a special handling tool through one of the top hatches and pulled into a movable radiation-shield transfer cask. This cask would transfer the targets

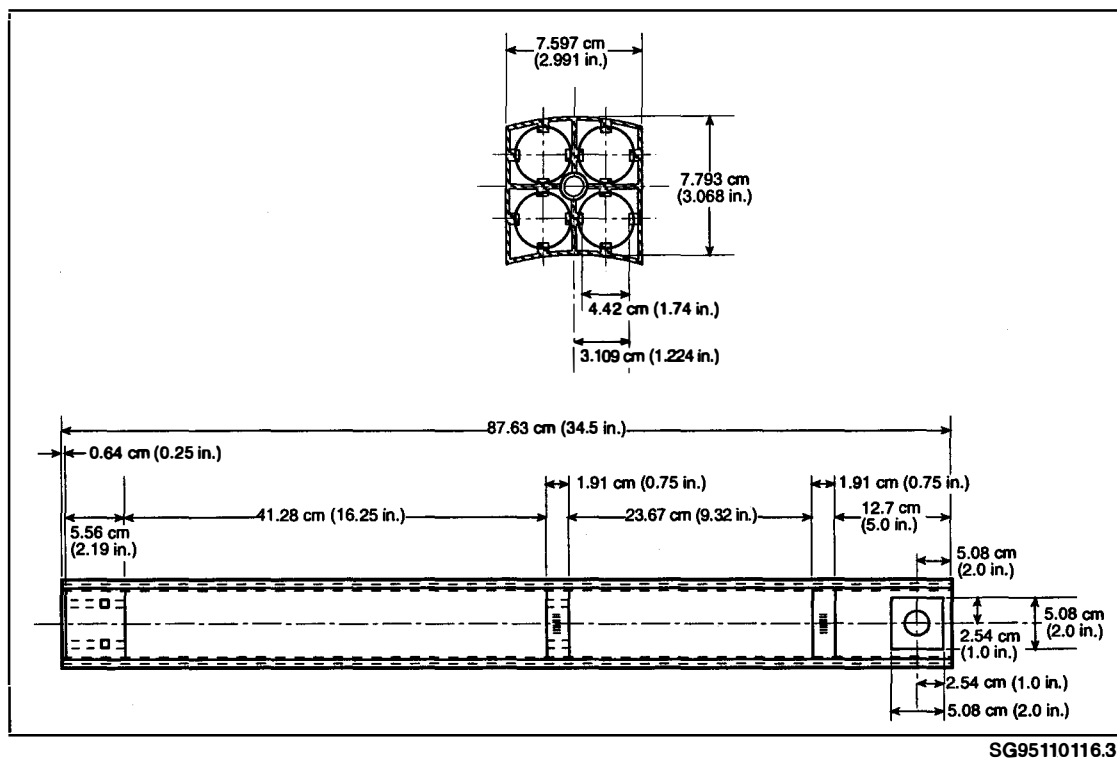


Figure 3-12. Target Stringer Assembly Diagram

and stringer to the holding tank where the four targets would be removed and loaded into a DOT-certified B-3 cask for transport to the Chemistry and Metallurgy Research Wing 9. Transfer from the reactor to the truck would require approximately 1 h.

The reactor recirculation flow rate ensures that targets fissioning at powers of 20 kW can be cooled (departure from nucleate boiling ratio of greater than 5). Simplistic heat transfer calculations show that target powers of greater than 20 kW should be achievable.

3.3.2.5 Target Transfer to the Hot Cell Facilities

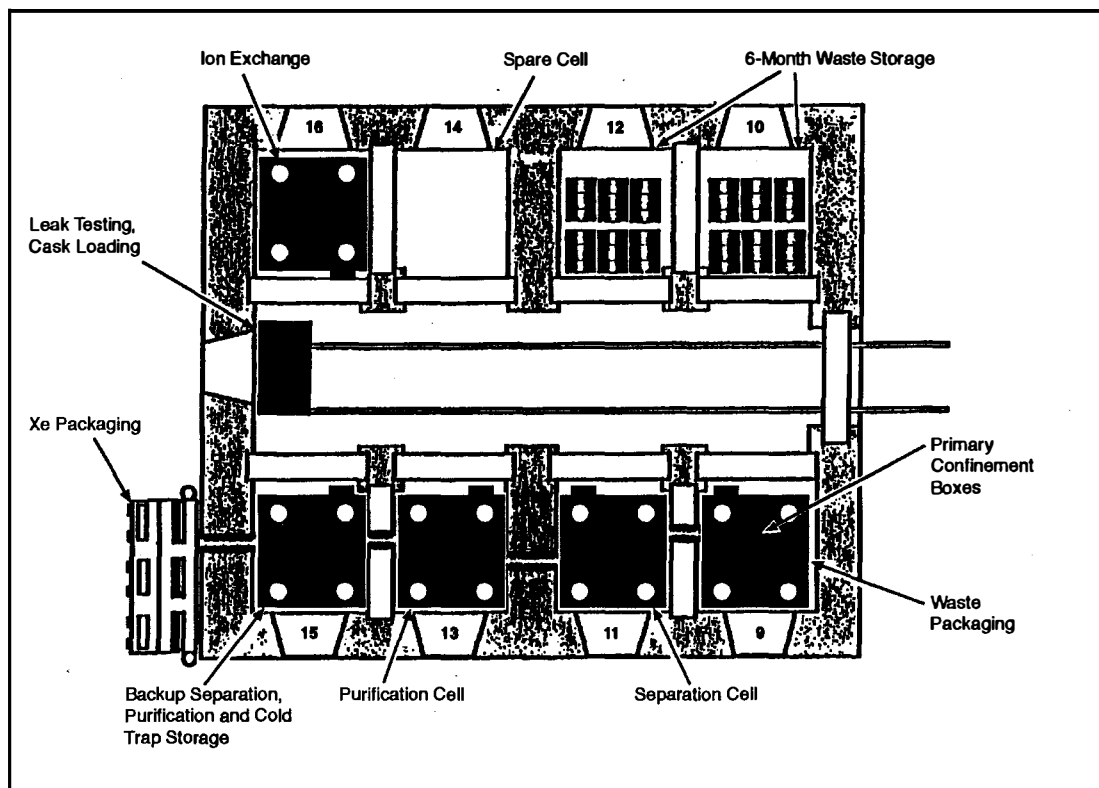
Truck transfer of the B-3 cask and insert containing one to four irradiated targets from the Omega West Reactor to the Chemistry and Metallurgy Research Facility, Wing 9 hot cell corridor would involve transport of less than 1 mi and require less than 1 h. The LANL possesses four B-3 casks onsite. The transfer would occur over LANL access controlled roads. The irradiated targets would be processed in the hot cells to glean the Mo-99 product.

3.3.2.6 Isotope Extraction at Hot Cell Facility

The LANL hot cells have adequate shielding to handle greater than 100,000 Ci of 1-MeV gamma-emitting radionuclides, which would be significantly greater than required for the proposed fission product separation process. A total of 16 such cells are resident in the Chemistry and Metallurgy Research, Wing 9 facility, with an additional two cells at each end, designated as blister (clean) cells for final product packaging. For processing four 20-kW targets at once, a source term of 64,000 Ci per cell is estimated. The exposure to hot cell operators is estimated to be 44 mrem per 2000 h of chemical processing. This exposure level is completely consistent with the LANL and the DOE ALARA goals. The ventilation system is more than adequate, with series-parallel paths consisting of a HEPA filter, charcoal bed, another HEPA filter, a delay volume, two stages of HEPA, two stages of charcoal, and the stack. The delay line allows for detection of a release and isolation of the stack before the release can reach the stack. Figure 3-13 is a plan view of the hot cell processing.

The targets in the B-3 cask would be unloaded in the receiving hall between the cell banks. In the receiving cell, the target would be connected to the product recovery line and the target would be opened. Fission gases would be removed through an iodine trap into a cold trap using liquid nitrogen. Following gas removal, an acid solution would be injected into the target to dissolve the plated uranium oxide. Both the iodine and the xenon trapped in the cold trap would be processed and packaged for shipment.

The liquid from the target dissolution would be drained into a bottle, treated to precipitate elemental iodine, and filtered to remove silver iodide. Molybdenum carrier (sodium hydroxide) would be added to the remaining solution. After several more steps of washing and removing impurities, including ruthenium, rhodium, and organic residues, the resulting product solution would contain sodium molybdate in dilute sodium hydroxide. Approximately 1200 to 1400 mCi/mL of Mo-99 would be expected per target.



SG95110116.43

Figure 3-13. Molybdenum-99 Hot Cell Processing (Plan View)

In the event of an operational difficulty with a hot cell, spare hot cells would exist in the same bay to preclude disruptions from routine operations.

To minimize releases during normal hot cell processing operations, LANL has designed process devices using three-way valves with O-ring seals for each step of the separation process. Use of this type of apparatus would minimize the release of noble gases present during the target puncture activities. The process device would also minimize the release of noble gases generated from the decay of halogens during the remaining process steps. Noble gases would be cold trapped periodically throughout the process.

The captured radioactive gases would be held in gas storage containers for approximately 40 days. The gas remaining at this time, consisting of approximately 0.5% of the xenon-133 and all of the krypton-85 that was trapped, would be released in the Chemistry and Metallurgy Research Facility stack ventilation flow path. This method of processing could be implemented at any of the other sites for the purpose of minimizing the release.

After completing the procedure for the purification of Mo-99, the product would be tested by gamma spectroscopic analysis of an appropriate aliquot of sample extracted from the product vial. Such analysis

would be useful not only in determining the nature of contamination, but in enabling the quality control laboratory to quantify the impurities and the Mo-99 content of the product vial. This information would be used to prepare the Material Safety Data Sheets that accompany the shipment.

The extraction process would also provide radioisotopes of xenon and iodine. Based on an irradiation power of 21 kW per target, each target could yield approximately 600 Ci of Mo-99, 200 Ci of iodine-131, and 600 Ci of xenon-133 one day after discharge from the reactor.

3.3.2.7 Product Shipment

The Mo-99 would be packaged in Type B accident-resistant packaging for shipment to the radiopharmaceutical companies. Air express class of shipments would be used with direct routing, if possible, to the customer city. Passenger carrying aircraft could be used, as the Transport Index (a federal requirement discussed in 49 CFR 175, basically specifying the dose rate from a radioactive shipment measured at 1 m from the package surface) of the Mo-99 package is within the limit allowed on passenger aircraft. Mo-99 that is produced at LANL would be distributed and shipped to radiopharmaceutical manufacturers using either the Los Alamos Airport, Santa Fe Airport, or the Albuquerque Airport.

3.3.2.8 Waste and Spent Nuclear Fuel Management

LANL has sufficient waste management facilities for the treatment and disposal of both solid and liquid radioactive wastes. From a waste handling perspective, LANL is a cradle-to-grave operation. Approximately 22.8 m³ (30 cu yd) of low-level waste (solid and liquid) would be generated per year from Mo-99 production activities at 100% of U.S. demand. LANL crushes solid waste, significantly minimizing the volume presented for disposition. Waste disposal is predicted to entail weekly disposals of 0.2 to 0.4 m³ (one to two 55-gal) drums. Waste from the target processing would be stored at the hot cell facility for approximately 3 months before processing. Liquid radioactive waste would be handled in TA-50, while solid, chemical and incidental mixed wastes would be handled in TA-54. The description of waste treatment and disposal is based on current practice and may change based on future decisions resulting from the DOE waste management study (1995a). Spent fuel from the reactor will be cooled for approximately 6 months and then transported to the onsite storage area. Both wet and dry spent fuel storage capability exists onsite. Spent nuclear fuel would be stored at LANL pending a decision on its final disposition in accordance with the SNF PEIS (DOE 1995b).

Storage Facilities. Onsite storage is available for both uranium and process consumables at the Chemistry and Metallurgy Research building. A large quantity of uranium-235 can be stored in the form of raw material, fabricated targets, and recoverable waste. Adequate storage is required to satisfy FDA Good Manufacturing Practice requirements. Storage for tubing, pipettes, glassware, and other items required for the chemical processing and separation is readily available adjacent to the hot cell facilities.

3.3.2.9 Required Modifications

Several categories of activities that had commenced prior to the termination of the Omega West Mo-99 initiative are discussed as follows. For discussion of modifications at the Chemistry and Metallurgy Research Facility, refer to Section 3.3.1.9.

Remediation of the leak associated with the underground pipe at the Omega West Reactor was a key issue that has been partially addressed. The leaking was terminated. The source, and cause, of the leak has been determined and analyzed. Excavation around the delay line was performed to assess the cause and determine the activities required for the repair. Non-destructive testing examinations proved that only the piping in contact with the soil showed any erosion. Analysis of piping samples determined that microbial action, in conjunction with stressed conditions, was the cause of the failure. Analysis concluded that it could be repaired.

Hardware upgrades and staffing plans are nearly complete. The hardware upgrades completed include several systems upgrades, one of which was nuclear instrumentation. Dual cooling towers and EPA-approved air monitoring equipment remain to be upgraded.

| A DOE Order 5480.23 (DOE 1992a) Nuclear Safety Analysis Report and a DOE Order 5480.22 (DOE
| 1992b) Technical Safety Requirements document have been drafted with comments incorporated from an
| initial review. Operating procedures reflecting the Safety Analysis Report have been prepared in accor-
| dance with DOE Order 425.1, Startup and Restart of Nuclear Facilities (1995d). The Maintenance Imple-
| mentation Plan and the Training Implementation Plan have been completed. All of these documents will
| require review, and possibly some revisions, to be finalized.

Process Validation Testing. Prior to production, some activity would be devoted to reactor physics experiments and process design activities. Such activities would require the procurement of some equipment or hardware. These activities are characterized as *proof-of-principle* studies that would support design and operational activities related to medical isotope production.

- Process Design - One or more prototype steel containment boxes and prototype processing equipment would be set up for examination of equipment performance, reliability, and adequacy of design.
- Reactor Physics Experiments - The existing calculations for isotope production in the Omega West Reactor would be verified by irradiating targets in the Omega West Reactor after the conversion to continuous operation is complete. This process would help determine configurations, reactor power, reactor operations, and the number of targets required to meet the U.S. demand for Mo-99.
- Prototype Target Fabrication - Test targets would be fabricated and tested to verify processes.

3.3.2.10 Estimated Schedule for Modification

A 1995 update to the schedule has been completed, and approximately 13 months from the date of the Record of Decision would be required to prepare the Omega West Reactor for operation. This schedule includes all the hardware modifications and document upgrades necessary. However, uncertainty is associated with the restart of a reactor that has been shut down for a long period of time. When the reactor is operational, LANL could produce Mo-99 within 5 months and attain the 100% production level 2 months thereafter.

3.3.3 Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory Alternative

The Oak Ridge National Laboratory (ORNL) is located 40 km (25 mi) west of Knoxville, Tennessee. The ORNL began operating in 1943 and is currently managed by Lockheed-Martin Energy Research, Inc. for the U.S. Department of Energy. The ORNL has facilities to produce isotopes via the fission process, as well as by neutron activation. The ORNL pioneered the production and distribution of radioisotopes for medical, research, and industry applications during the 1950s and the 1960s and is experienced in all aspects of radioisotope production.

3.3.3.1 Description of the Alternative

The ORNL would produce Mo-99 by irradiating Cintichem type targets using the Oak Ridge Research Reactor. A nearby facility, the Radioisotope Development Laboratory, would be dedicated for Mo-99 processing. A separate area in the Radioisotope Development Laboratory would be set up for uranium-235 target fabrication. Processed Mo-99 would be shipped to the radiopharmaceutical companies for further purification and distribution, using the Knoxville airport which is 48 km (30 mi) from ORNL.

3.3.3.2 Existing Facilities

The ORNL would ship the low-level waste generated by the Mo-99 production process to the Nevada Test Site. All other aspects of the production process would be conducted using existing site facilities. The Oak Ridge Research Reactor would be restarted to irradiate Mo-99 production targets. The Oak Ridge Research Reactor had been operated as a Class A reactor (≥ 20 MW), but would be restarted as a Class B reactor (< 20 MW) and redesignated as the Medical Isotope Production Center. The Radioisotope Development Laboratory would require minor modifications to conduct target fabrication and processing.

3.3.3.3 Target Fabrication at ORNL

Target fabrication would be carried out on the second floor of the Radioisotope Development Laboratory using glove boxes, each having a separate ventilation system and provided with HEPA filters. The target fabrication process would be conducted as described in Section 3.3.1.3.

3.3.3.4 Target Irradiation Activities

Currently, the Oak Ridge Research Reactor is not in operation. Commissioned in 1958 at the X-10 site of the Oak Ridge Reservation, the Oak Ridge Research Reactor is a 30-MW tank-type reactor. The Oak Ridge Research Reactor uses Materials Test Reactor type highly enriched uranium fuel (93%) elements and beryllium reflector elements in a seven-by-nine element rectangular lattice. Neutron moderation and core cooling are provided through forced convection of demineralized water. The Oak Ridge Research Reactor provides a maximum thermal neutron flux of 5×10^{14} n/cm²-s and an average thermal flux of 1.6×10^{14} n/cm²-s.

Another feature of the Oak Ridge Research Reactor is the location of its reactor tank in one end of a water-filled rectangular pool. This tank provides shielding for the core, experiments, and refueling operations, and supplies researchers with easy access to the core region. The control rod drives are operated from below the reactor. Safety features include a filter scrubber system and a dynamic confinement building around the reactor to protect the offsite population against any accidental radioactive releases. The adjoining storage pools provide shielding and storage for up to 180 depleted fuel elements.

The Oak Ridge Research Reactor has two hot cells located above one end of the reactor storage pool. These hot cells allow irradiated samples to be moved under water from the core region directly into the hot cell. Depleted fuel and control elements can also be removed from the Oak Ridge Research Reactor through the rectangular hatch at the top of the reactor tank and then moved under water to the storage pool area or to the adjacent hot cell for experimentation. A 20-ton crane traverses the entire bay area.

A typical outage in the past varied from 2 to 3 days after operating at a power level of 30 MW for 4 weeks. The refueling operation was handled manually from the bridge over the pool.

The primary mission of the Oak Ridge Research Reactor was to 1) test the materials and potential fuels for power reactors; 2) facilitate solid state physics research; and 3) to produce and supply radioisotopes to medical, industrial, and academic users.

The reactor was used for basic studies on the properties of metals, alloys, ceramics, and nuclear fuels, as well as for neutron scattering and spectroscopy. Oak Ridge Research Reactor's neutron activation facilities were designed for radioisotope production. Due to the Oak Ridge Research Reactor's high neutron flux, large sample capacity and flexibility, ORNL could produce, process, package, and distribute 25 different isotopes, such as phosphorous-32, Mo-99, iodine-131 for medical applications, and iridium-192 for industrial radiography, for the entire western hemisphere. Because governmental policies dictated that ORNL produce only those isotopes commercial suppliers do not market, Oak Ridge Research Reactor phased out its production of major radioisotopes by the mid-1960s.

The reactor was shut down briefly in 1983, due to a leak in the 91-m (300-ft) pipe carrying the primary coolant to the heat exchanger located outside the reactor building. This aluminum piping was originally designed for 10 years of reactor operation. Subsequent investigation had revealed the pipe had corroded

from the outside, due to the spring water (ground water) surrounding the exterior of the pipe. The leak was fixed and the reactor resumed operation the same year. The leak was not related to reactor chemistry and all other reactor systems were in an operational status.

In 1987, Oak Ridge Research Reactor's core had been modified to accept low enriched uranium (<20%) as part of an experimental study in collaboration with Argonne National Laboratory (ANL). The Oak Ridge Research Reactor was shut down later in 1987 due to lack of programmatic support, as improved irradiation and neutron scattering facilities at the ORNL High Flux Isotope Reactor became available.

If selected for Mo-99 production, the Oak Ridge Research Reactor would be restarted at a power level of 10 MW using either highly enriched uranium or low enriched uranium fuel or using a mixed core of both types of fuel. Transition to a core using all low enriched uranium fuel would be performed during the first two years of full power operation. For every 2 to 3 months of operation at 10 MW power, Oak Ridge Research Reactor could require an outage time of 12 h to 3 days for refueling, providing an equivalent availability factor of >0.90. The primary mission of the reactor would be the production of Mo-99. Some costs could be offset by sharing expenses with other users of its experimental facilities on a non-interference basis.

Operating on an low enriched uranium fuel at 10 MW power, the Oak Ridge Research Reactor would irradiate up to 10 target stringers per week at an average thermal neutron flux of 8.7×10^{13} n/cm²-s. The target loading and target number per stringer would be adjusted to produce an aggregate target power greater than 500 kW. Four targets would be housed in each stringer, similar to the stringers at Cintichem. Targets would be introduced and retrieved on a daily basis using a quick change procedure. The total Mo-99 content of all the 40 targets, with an integrated target power of 500 kW at the time of target retrieval, would be approximately 19,600 actual Ci after processing. This amount would supply over 3000 6-day curies to the radiopharmaceutical houses. The Oak Ridge Research Reactor is capable of supplying additional Mo-99 capacity to well above 120% of the current U.S. demand.

3.3.3.5 Target Transfer to the Hot Cell Facility

The irradiated target would be transferred into a transfer cask within the pool and transported (less than 1000 ft) to the receiving hot cell in the Radioisotope Development Laboratory located adjacent to the Oak Ridge Research Reactor building that would become the Medical Isotope Production Center (MIPC) (Figure 3-14). Four shielded manipulator cells and all necessary support systems would be dedicated to processing Mo-99 (Figure 3-15). Irradiated targets would be processed using the Cintichem process per the schedules, commensurate with the production and delivery requirements.

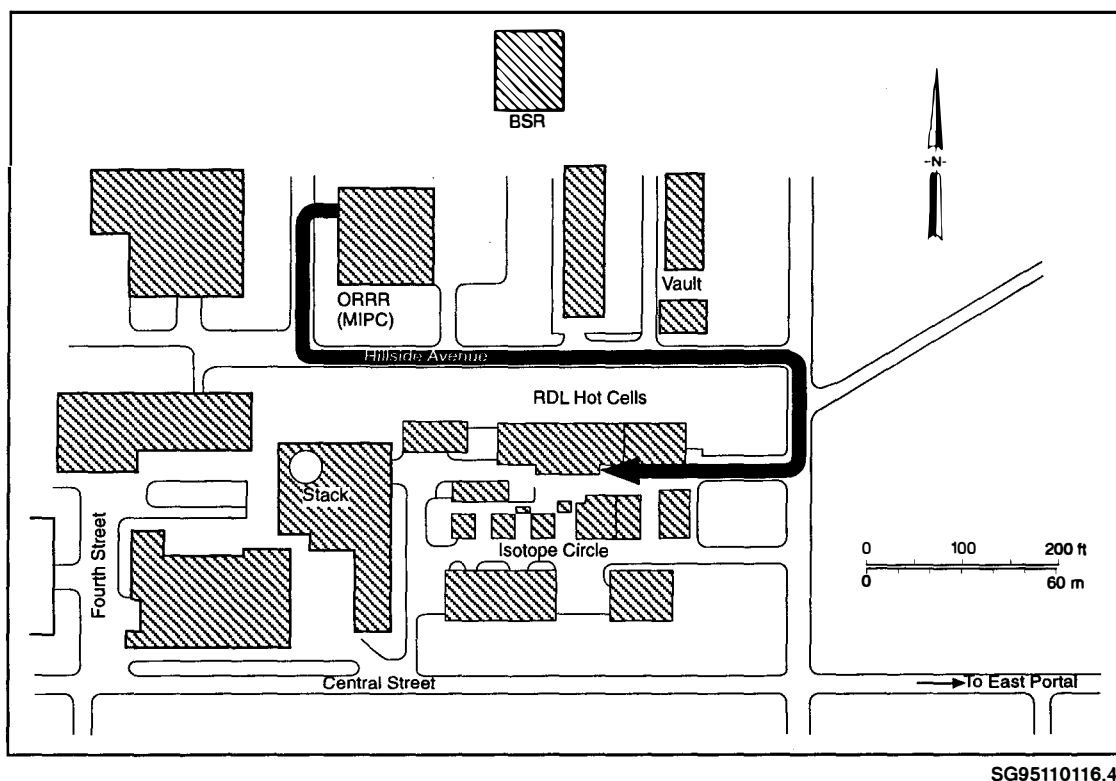
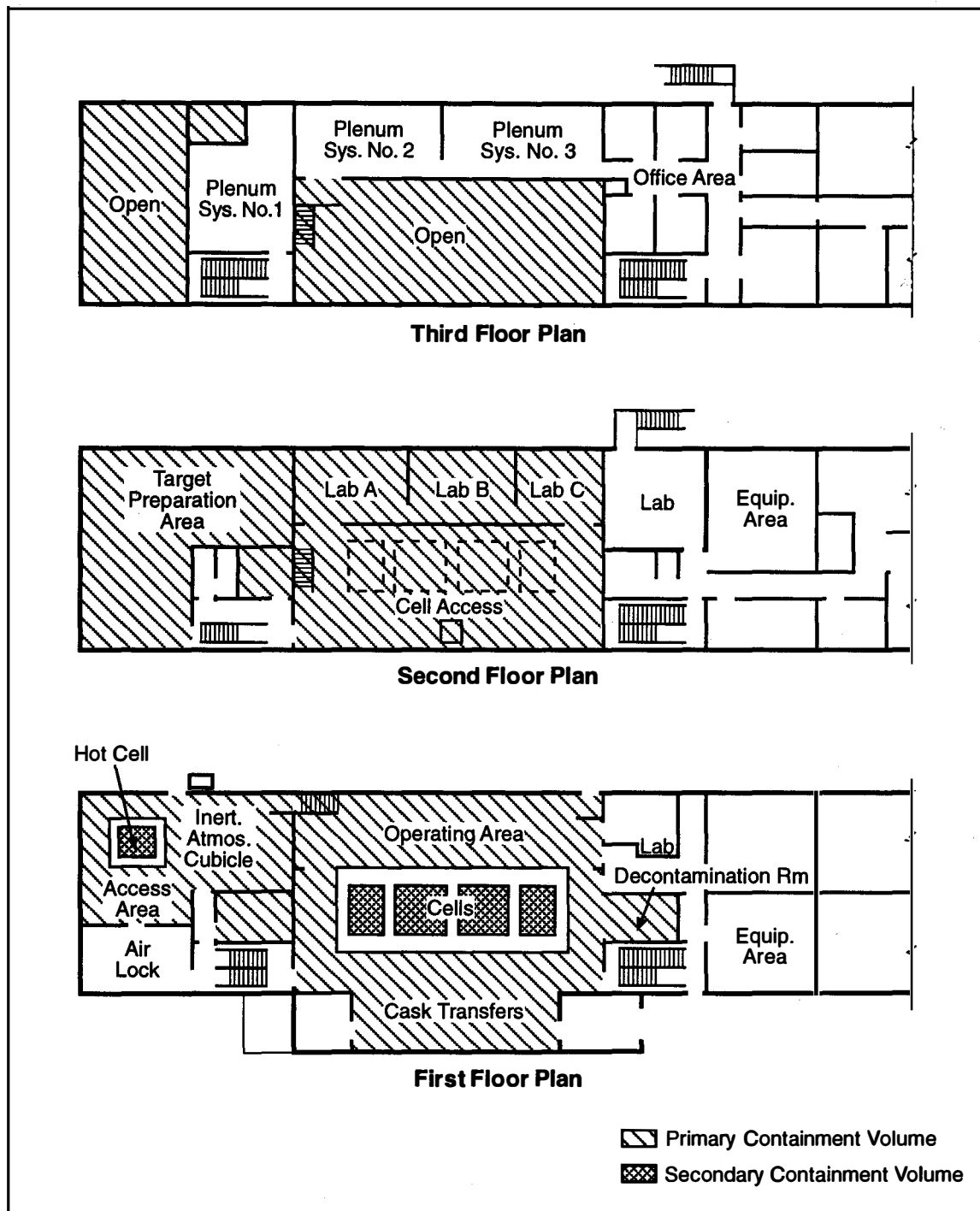


Figure 3-14. Relative Locations of the Bulk Shielding Reactor, Oak Ridge Research Reactor, and the Radioisotope Development Laboratory Hot Cells

3.3.3.6 Isotope Extraction at the Hot Cell Facility

The target would be opened in a fission gas recovery system provided with cryogenic traps to recover radioactive iodine and xenon isotopes. The uranium containing Mo-99 and other fission products would be dissolved using an acid solution. The amount and the specific activity of Mo-99 obtained would vary according to the target loading, irradiation time, and the target power.

The liquid from the target dissolution would be drained into a bottle, treated to precipitate elemental iodine, and filtered to remove silver iodide. Molybdenum carrier (sodium hydroxide) would be added to the remaining solution. After several more steps of washing and removing impurities, including ruthenium, rhodium, and organic residues, the resulting product solution would contain sodium molybdate in dilute sodium hydroxide. Approximately 1200 to 1400 mCi/mL of Mo-99 would be expected per target. In the event of an operational difficulty with a hot cell, spare hot cells would exist in the same bay to preclude disruptions from routine operations.



SG95110116.40

Figure 3-15. Layout of the Three Floor Levels of the Radioisotope Development Laboratory Facility

After completing the procedure for the purification of Mo-99, the product would be tested by gamma spectroscopic analysis of an appropriate aliquot of sample extracted from the product vial. Such analysis would be useful not only in determining the nature of contamination, but in enabling the quality control laboratory to quantify the impurities and the Mo-99 content of the product vial. This information would be used to prepare the Material Safety Data Sheets that accompany the shipment.

The extraction process would also provide radioisotopes of xenon and iodine. Based on an irradiation power of 21 kW per target, each target could yield approximately 600 Ci of Mo-99, 200 Ci of iodine-131, and 600 Ci of xenon-133 one day after discharge from the reactor.

3.3.3.7 Product Shipment

The Mo-99 would be packaged in Type B accident-resistant packaging for shipment to the radio-pharmaceutical companies. Air express class of shipments would be used with direct routing, if possible, to the customer city. Passenger carrying aircraft could be used, as the Transport Index (a federal requirement discussed in 49 CFR 175, basically specifying the dose rate from a radioactive shipment measured at 1 meter from the package surface) of the Mo-99 package is within the limit allowed on passenger aircraft. The Knoxville airport is located 48 km (30 mi) from ORNL and is serviced by the major airlines.

3.3.3.8 Waste and Spent Nuclear Fuel Management

Approximately 73.2 m³ (95.7 cu yd) of low-level waste (solid and liquid) would be generated per year from Mo-99 production activities at 100% of U.S. demand. Radioactive waste from target processing would be held in the hot cell area for approximately 6 months. After this radioactive decay period, the waste would be solidified, packed, and transferred to storage on above-ground pads. The waste would then be shipped to the Nevada Test Site for final disposal. Incidental mixed waste would be stored in permitted mixed waste areas. The description of waste treatment and disposal is based on current practice and may change based on future decisions resulting from the DOE waste management study (1995a). Oak Ridge Research Reactor has the capacity to handle spent nuclear fuel onsite. Spent nuclear fuel would be stored at Oak Ridge pending a decision on its final disposition in accordance with the SNF PEIS (DOE 1995b).

3.3.3.9 Required Modifications

Oak Ridge Research Reactor Modifications. The Oak Ridge Research Reactor has been maintained for some time in standby mode and would require modification to restart. Use of this reactor would require the preparation of a Safety Analysis Report, and revisions of the technical specifications and of the operating procedures. Certain licenses and permits would also be necessary. Before restart, an Operational Readiness Review would also be required.

Changes to the current physical plant would be needed: the control room upgraded, a new resin slurry system installed, and new pumps/plate type heat exchangers procured for the Oak Ridge Research Reactor

basement. As required, out-of-service instrumentation and equipment would be assessed and repaired. New reflector pieces and hold-down arms would be fabricated, as well as six shim rods (if low enriched uranium-based operation is required).

Radioisotope Development Laboratory Modifications. The modifications to the Radioisotope Development Laboratory would include customizing the second floor for the target fabrication and customizing the hot cells to allow irradiated Cintichem-type target processing for Mo-99. Training of ORNL radiochemistry and health physics personnel for Mo-99 operations would also be necessary.

Process Validation Testing. Prior to production, process validation testing would be conducted. The process described in Section 3.3.1.9 is generally applicable to the Oak Ridge Research Reactor.

3.3.3.10 Estimated Schedule for Modification

Approximately 30 months from the date of the Record of Decision would be required to prepare the Oak Ridge Research Reactor for operation (estimated startup in August 1998). This schedule includes all the necessary hardware modifications and document upgrades.

3.3.4 Power Burst Facility/Test Area North: Idaho National Engineering Laboratory Alternative

The U.S. Atomic Energy Commission, a predecessor of DOE, established INEL (formerly known as the National Reactor Testing Station) to build, test, and operate various types of nuclear reactors, support plants, and associated equipment. Since its establishment in 1949, DOE and its predecessor agencies have built 52 reactors at INEL. In support of the DOE reactor research program and as part of the spent nuclear fuel reprocessing program, INEL has received spent nuclear fuel from more than 30 offsite sources, including naval reactors, university reactors, commercial reactors, and DOE research reactors, as well as fuels fabricated in the U.S. and irradiated in foreign reactors.

In 1974, the National Reactor Testing Station became INEL. The INEL mission broadened to include research and engineering for nonnuclear programs and environmental restoration and waste management activities. In 1980, INEL further expanded its mission to include isotope production for medical, industrial, and research applications.

3.3.4.1 Description of the Alternative

This alternative would require restart of the Power Burst Facility and modifications to other INEL facilities to produce Mo-99. The location of INEL and the location of the facilities discussed in the following sections are shown in Section 4. The major proposed activities would include fabricating uranium targets at INEL and then shipping the targets to the Power Burst Facility for irradiation. The irradiated targets would be processed at Test Area North or at stand-alone hot cells constructed in a

suitable location adjacent to the Power Burst Facility. The Mo-99 product would be shipped to radio-pharmaceutical companies via the Idaho Falls Airport. Low-level radioactive wastes would be packaged and shipped to the Radioactive Waste Management Complex at INEL.

3.3.4.2 Existing Facilities

Existing facilities at INEL would be used for the four fundamental Mo-99 production operations. An onsite facility would be modified to fabricate targets (several adequate facilities exist on the site). The Power Burst Facility would be restarted to irradiate Mo-99 production targets. Hot cells at the Test Area North would be modified, or new hot cells would be constructed, to process the targets. Radioactive wastes would be disposed onsite at INEL.

3.3.4.3 Target Fabrication at INEL

The target fabrication processes that were developed by Cintichem, and which are being refined by LANL, could be implemented at a number of facilities at INEL. The target fabrication process would be the same as that being developed by LANL, described in Section 3.3.1.3.

Because special facilities are not required, the target production area would be located at the Test Area North in a building similar to the Experimental Test Reactor Critical Facility annex or the lower floor of the Materials Test Reactor building. Targets would be fabricated and stored onsite until needed for irradiation in the Power Burst Facility.

3.3.4.4 Target Irradiation Activities

The unirradiated targets would be transported by truck to the Power Burst Facility for irradiation. The Power Burst Facility consists of an low enriched uranium oxide-fueled, epithermal reactor, plus supporting systems and equipment. The facility is housed in two buildings, a reactor building, and a control building. The reactor building is located approximately 0.8 km (0.5 mi) northwest of the control building. The reactor is currently in an operational standby status.

The driver core installed in the Power Burst Facility is the original reactor fuel core. This core has been operated for 24,925 MWh with calculations to indicate that 100,000 to 150,000 MWh remain in the installed core and unirradiated fuel rods on hand.

In 1987, a program was proposed to DOE by the Idaho Brain Tumor Center for using the Power Burst Facility as a neutron source for treating a certain type of brain tumor with Boron Neutron Capture Therapy. Several peer reviews failed to support maintaining the Power Burst Facility in standby mode solely for the developing technology. As a result of the peer reviews, and because no other program could be identified for the Power Burst Facility, DOE-Idaho directed the contractor to place the Power Burst Facility in a

shutdown condition. This direction was given on April 8, 1992. However, Idaho Brain Tumor Center holds a lease option on the Power Burst Facility until January 1997. The Power Burst Facility could be used to produce Mo-99 and, concurrently, as a Boron Neutron Capture Therapy treatment center.

The targets would be irradiated at a power level of approximately 20 kW per target. Three configurations of the Power Burst Facility core would be suitable for Mo-99 production. These configurations are identified:

1. Removal of the central experimental tube and installation of a Mo-99 target holder with a diameter of approximately 21 cm (8 in.).
2. Removal and replacement of four installed annular transient rods with a special irradiation fixture for Mo-99 production targets.
3. Removal of one or more of the six types of fuel canisters and replacing this position(s) with a Mo-99 irradiation target holder.

The normal steady state power level of the Power Burst Facility has been reduced from the published value of 28 MW to 10 MW for these production calculations. This power reduction will reduce the flux densities for the fuel and central core test space to 4.5×10^{12} and 3.7×10^{13} n/cm²-s, respectively. The following summary provides the corresponding Mo-99 production rates for the three core configuration options previously identified.

1. Power Burst Facility Center Test Space: Removing the central experimental tube and machining a special holder could provide space for at least 19 Cintichem type Mo-99 production targets. The process would then have the capability of producing approximately 2400 6-day Ci of Mo-99 every 6 days of reactor operation. This arrangement would allow sufficient coolant flow to limit increases in core heat flux.
2. Annular Transient Rod Positions: If additional Mo-99 production is required, the four transient rod positions (not required for steady state power operation) could be utilized. Each transient rod location could contain two, or possibly three, Mo-99 production targets. Even with lower core thermal neutron flux, these four locations could potentially produce another 600 to 900 6-day Ci of Mo-99 every 8 to 10 days of reactor operation (2000 to 3000 Ci at reactor shutdown).
3. Fuel Canister Removal: Fuel canisters contain from 28 to 62 fuel pins per canister. Removal of a 28-pin fuel canister and replacement with a special Mo-99 production holder is also an option. The addition of highly enriched uranium in the Mo-99 production targets would partially offset the removal of 18.5 wt% uranium-235 Power Burst Facility fuel pins. Detailed thermal hydraulic and multigroup diffusion theory analyses would be required to accurately determine feasibility for this configuration. The issue of target accessibility for these positions would also need to be addressed.

3.3.4.5 Target Transfer to the Hot Cell Facility

The shipment of irradiated Mo-99 targets from the Power Burst Facility reactor to the Test Area North processing facility could be accomplished with an approved container having a site-approved transport plan. The DOT- or NRC-approved containers are not required for transport of the targets within the INEL. However, transport of the targets must be performed in accordance with DOE Order 0460.2 (DOE 1995e). Several containers not approved by DOT were identified that could be used for this purpose. These containers included the TFBP-1, WE #2, or Advanced Test Reactor spent fuel cask. In addition, the CNS1-13, although not approved for DOT transport, could be included in an addendum transport plan that could permit its use for transport of Mo-99 targets within the INEL. All of these containers could be handled and loaded from the Power Burst Facility reactor canal area. All would require the preparation of a new transport plan.

3.3.4.6 Isotope Extraction at the Hot Cell Facility

The target would be opened in a fission gas recovery system provided with cryogenic traps to recover radioactive iodine and xenon isotopes. The uranium containing Mo-99 and other fission products would be dissolved using an acid solution. The amount and the specific activity of Mo-99 obtained would vary according to the target loading, irradiation time, and the target power.

When the irradiated target element is received in the process cell, it would be punctured to vent the iodine, xenon, krypton and other fission product gases into a liquid nitrogen cold trap for capture as a liquid or solid. These cold-trapped gases would then be allowed to vaporize and be collected in gas collection containers.

The liquid from the target dissolution would be drained into a bottle, treated to precipitate elemental iodine, and filtered to remove silver iodide. Molybdenum carrier (sodium hydroxide) would be added to the remaining solution. After several more steps of washing and removing impurities, including ruthenium, rhodium, and organic residues, the resulting product solution would contain sodium molybdate in dilute sodium hydroxide. Approximately 1200 to 1400 mCi/mL of Mo-99 would be expected per target. In the event of an operational difficulty with a hot cell, spare hot cells would exist in the same bay to preclude disruptions from routine operations.

After completing the procedure for the purification of Mo-99, the product would be tested by gamma spectroscopic analysis of an appropriate aliquot of sample extracted from the product vial. Such analysis would be useful not only in determining the nature of contamination, but in enabling the quality control laboratory to quantify the impurities and the Mo-99 content of the product vial. This information would be used to prepare the Material Safety Data Sheets that accompany the shipment.

The extraction process would also provide radioisotopes of xenon and iodine. Based on an irradiation power of 21 kW per target, each target could yield approximately 600 Ci of Mo-99, 200 Ci of iodine-131, and 600 Ci of xenon-133 one day after discharge from the reactor.

3.3.4.7 Product Shipment

The Mo-99 would be packaged in Type B accident-resistant packaging for shipment to the radio-pharmaceutical companies. Air express class of shipments would be used with direct routing, if possible, to the customer city. Passenger carrying aircraft could be used, as the Transport Index (a federal requirement discussed in 49 CFR 175, basically specifying the dose rate from a radioactive shipment measured at 1 meter from the package surface) of the Mo-99 package is within the limit allowed on passenger aircraft. Product movement would be from the processing facility to the Idaho Falls airport, approximately 72.5 km (45 mi) away.

3.3.4.8 Waste and Spent Nuclear Fuel Management

INEL has the capability to handle onsite all of its generated waste. From a waste handling perspective, INEL is a cradle-to-grave operation. Approximately 85.2 m³ (111.4 cu yd) of low-level waste would be produced per year from Mo-99 production activities at 100% of U.S. demand. Waste would be stored in the hot cell facility for approximately 6 months to permit decay of short-lived radionuclides. All generated waste would be handled through the established waste management processes at INEL in accordance with all applicable federal, state, local, DOE, and INEL requirements. Waste treatment and disposal practices may change based on future decisions resulting from the waste management study (DOE 1995a). Adequate wet and dry spent fuel storage exists onsite. Final disposition of spent fuel will be in accordance with the SNF PEIS (DOE 1995b).

3.3.4.9 Required Modifications

Power Burst Facility Modifications. The Power Burst Facility has been maintained in standby condition and is anticipated to require a few modifications to be able to restart. A significant portion of the reactor instrumentation would need to be replaced and all of the systems would need to be tested to determine operability. Use of the Power Burst Facility would also require the preparation of a revised safety analysis report for Mo-99 production.

The Power Burst Facility SAR and Technical Safety Requirements documents would have to be reviewed and upgraded to address the new facility mission, and to reflect the current requirements of the DOE Orders 5480.22 (1992b) and 5480.23 (1992a). Additionally, the restart of the Power Burst Facility would require an Operational Readiness Review.

In addition to the facility modifications required, Power Burst Facility reactor core modifications would be required to support Mo-99 target irradiation. Several modifications would be required to conduct medical isotope production. Besides modifying the central cavity, the reactor control system would need to be modified for a continued steady state, non-pulse mode. The transient rods would need to be removed and fixtures for target irradiation placed in the vacant locations. All material removed from the central cavity would require disposal, as would the transient rods and mechanisms. Cooling flow to the central cavity would need to be appropriately established along with the normal core cooling flow in lieu of the

contained loop that currently exists. Flow balance valves for the central irradiation cavity would have to be designed and installed to ensure that appropriate target cooling flow is established without flow induced vibration of the targets occurring. The core would need to be redesigned to supply a hardened spectrum of neutrons to the central irradiation cavity. Concentration of the power to the core center would be needed to establish the appropriate flux level, without needing to operate the reactor above 10 MW, to make the facility competitive regarding fuel utilization.

Hot Cell Facility Modifications. Two options were considered in evaluating the feasibility of utilizing existing processing facilities at the INEL. These options included either using existing facilities or purchasing stand-alone process cells that could be placed in any convenient location at the INEL.

The hot cell annex, at the Test Area North hot cell area, was considered as an existing facility option for the recovery of the Mo-99 from the irradiated targets. This facility is in an acceptable state of repair and only minor facility modifications would be required to place it in operation. The facility safety documentation has undergone a recent upgrade and would provide a nearly complete basis for facility operation and Mo-99 production there. Transportation of irradiated targets from the Power Burst Facility to this location would be the most difficult barrier to the use of the Test Area North facility.

Unlike other hot cell alternatives at INEL, transport to Test Area North requires travel over approximately 8 km (5 mi) of State Highway 33. Transportation in this area requires a DOT-approved container. Either the BMI-1 cask or the GE-2000 cask could be used for this purpose. The DOE currently possesses both of these casks.

The Test Area North hot cells were not considered as an acceptable existing hot cell facility because those cells are currently in use for other medical and industrial isotope production programs. Additionally, the facility is presently classified as a hazard Class II facility. This classification limits the fissile material inventory in the facility to less than 350 g of uranium-235 in a moderated condition. The Test Area North hot cells, therefore, are not an option for the processing of irradiated Mo-99 targets.

Mo-99 production feasibility studies addressed the possibility of conducting all processing in stand-alone cells purchased from a commercial supplier. Such an arrangement would be of great financial advantage, if these cells could be located in an existing facility close to the Power Burst Facility and possibly even be considered as a single facility with the Power Burst Facility. This arrangement would eliminate the cost of preparing additional safety documents for added facilities, and it would permit Power Burst Facility staff to conduct processing operations, as well as reactor operation. This evaluation determined that anticipated radiation and airborne activity levels in the Power Burst Facility building during reactor operation are not consistent with those required for the continuous occupancy that would be required for Mo-99 processing activities. However, it may be feasible to erect an additional annex to the Power Burst Facility structure, shielded from the main reactor building, and connected to existing Power Burst Facility effluent ventilation and radiation monitoring systems. Such a facility would provide great advantage by the use of stand-alone manufactured cells and would eliminate transportation time and liability.

Additionally, the hot cells chosen would require the Mo-99 Process Line Installation and Quality Control Laboratory as follows:

- **Mo-99 Process Line Installation** - Processing equipment unique to isotope production would have to be procured and installed prior to production. Examples include extraction process equipment and waste processing equipment.
- **Quality Control Laboratory** - This laboratory would be required by the approved FDA procedure. The Quality Control Laboratory requires a minimal amount of space (no significant construction) and equipment, such as ventilated shielded glove boxes and detection equipment. Additionally, small shielding enclosures would be installed around selected equipment.

Process Validation Testing. Prior to production, process validation testing would be conducted. The process described in Section 3.3.1.9 for the Annular Core Research Reactor is generally applicable to the Power Burst Facility.

3.3.4.10 Estimated Schedule for Modification

The INEL option would be capable of producing Mo-99 22 months after the Record of Decision and in a full production mode after an additional 6 months.

3.4 Alternatives Considered and Dismissed

The following alternatives were considered as candidates for the domestic production source of Mo-99, but were dismissed from detailed consideration because they do not satisfy the screening criteria set forth in Section 3.1.1. A brief description of each alternative and the reason(s) for its dismissal are presented in this section.

3.4.1 Other Federal Facilities

3.4.1.1 Advanced Test Reactor - Idaho National Engineering Laboratory

The Advanced Test Reactor is a 250-MW pressurized water reactor, light water moderated and cooled, with a beryllium reflector. It operates with a cycle of 30 to 45 days of operation followed by 7 to 10 days of refueling. The reactor vessel is sealed during operation so access to the reactor internals is available only during reactor shutdown/refueling.

Two Mo-99 production methods were considered at the Advanced Test Reactor (DOE 1995f). Neither method met the screening criteria.

In the first method, the standard Cintichem type targets would be placed in one of the irradiation positions in the core, at the start of an operating cycle, and then irradiated for the ensuing 30 to 40 days. At the end of the cycle, the target would be removed from the reactor and processed in the hot cells onsite. The primary problem with this method of Mo-99 production at the Advanced Test Reactor is the reactor's operating characteristics. The Advanced Test Reactor operates for 30 to 45 days, followed by a week to 10 days of refueling. Mo-99 would not be produced during this period when the reactor is shut down. Therefore, the Advanced Test Reactor would not provide a reliable continuous supply of Mo-99--a basic requirement of the project. A second reason the Advanced Test Reactor would not be suitable for this project is the long irradiation period. The molybdenum isotopes from 95 through 100 are all produced from fission. All are stable with the exception of Mo-99. Due to the short half life of Mo-99, the quantity would equilibrate within about 15 days of target irradiation, while the other isotopes continue to build. The specific activity, or Ci of Mo-99 per gram of elemental molybdenum, begins to decrease rapidly after approximately 8 days of target irradiation. The long irradiation periods required by the Advanced Test Reactor operating cycle impact the quality of the product, due to the low specific activity.

In the second method, mini-targets, about 10.2 to 12.7 cm (4.0 to 5.0 in.) long, similar to the Cintichem type targets (coated with $\approx$ 5 g uranium-235), would be placed in a hollow tube, called a *rabbit*. The hollow tube containing the target would be inserted remotely in the core and irradiated for a predetermined period (few hours to a few days) and then processed in the hot cell similar to the regular targets. The rabbit would permit the removal/insertion of a target through a remote manipulator during reactor operation. This approach would overcome the long reactor operating cycle shortcoming. The regular 45.7-cm (18.0-in.) long Cintichem targets could not be accommodated in the rabbit. Instead, a target $\sim$ 11.4 cm (4.5 in.) would be used. Such a smaller target, that is significantly different from the Cintichem design, may warrant additional scrutiny by the FDA for granting a Drug Master File.

To have sufficient cooling of the target during irradiation, a hydraulically cooled rabbit, instead of a pneumatically cooled device, would be needed. The rabbit facility would be a multiple facility in one of the Advanced Test Reactor lobes and would contain six separate hydraulic rabbit tubes. Each tube would operate independently of the others. Target powers in excess of 30 kW per target are possible, due to the forced hydraulic cooling capability. The aggregate target power from this configuration would be approximately 200 kW, less than half the target power required for full Mo-99 production. This limitation precludes the rabbit method from further consideration.

On the basis of the reasons stated, it is apparent that Advanced Test Reactor cannot produce Mo-99 on a schedule or in quantities necessary to meet the selection criteria. Therefore, this alternative is rejected.

3.4.1.2 National Institute of Standards and Technology Reactor/Armed Forces Radiobiology Research Institute Hot Cell Facilities

This alternative considered the use of the National Institute of Standards and Technology reactor in Gaithersburg, Maryland, to irradiate the targets, and the hot cell facilities at the Armed Forces Radiobiology Research Institute in Bethesda, Maryland, to process Mo-99.

The National Institute of Standards and Technology has a tank type reactor that achieved full operational power of 20 MW in 1969. Heavy water serves as the primary coolant, moderator, and the reflector. The primary coolant is circulated through forced convection. As the purity of heavy water is very important, the reactor vessel is completely sealed during the operation and pressurized with helium. The fuel elements are Materials Test Reactor type containing 350 g of 93% uranium-235. Each element is 1.5 m (5.0 ft) in length, with two 28-cm (11-in.) fuel columns, separated by a 17.8-cm (7.0-in.) long column of light water that serves as a neutron trap.

The National Institute of Standards and Technology reactor is not suitable for Mo-99 production for the following reasons:

- The mission of the National Institute of Standards and Technology reactor is to provide its neutron activation, depth profiling, radiography, and its cold neutron facilities to nearly 1200 customers, worldwide. It normally has a significant waiting list for its use. The Mo-99 production project, if adopted, would severely hurt its primary mission.
- The reactor is a sealed tank type and the targets cannot be moved in and out of the reactor without shutting down the reactor. The 35-day fuel cycle of the tank precludes this reactor from using it for Mo-99 mission, due to specific activity considerations.
- The reactor is provided with a rabbit, a mechanical device allowing access to the reactor without shutting it down. However, the rabbit can admit samples only as large as 2.5 cm (1.0 in.) diameter by 7.6 cm (3.0 in.) long. These parameters are not adequate for the Cintichem target irradiation. A typical Cintichem target measures 3.19 cm (1.25 in.) in diameter by 45.7 cm (18.0 in.) long.

3.4.1.3 One or More TRIGA Reactors

TRIGAs are a type of reactor built by General Atomics. They are designed for training, research, and isotope production, hence the acronym TRIGA. A distinguishing characteristic of the TRIGA design is the exceptionally large prompt negative temperature coefficient due to the zirconium hydride in the fuel. This characteristic means that any increase in temperature results in a decrease in reactor power. A large TRIGA core with reduced leakage can have an equilibrium core lifetime of approximately 6000 MW/day, while a smaller, high-leakage core would be expected to have a significantly smaller equilibrium core lifetime. TRIGA fuel can be purchased at 8-1/2 wt% (38 g uranium-235), 12 wt% (49 g uranium-235), and 20 wt% (97 g uranium-235).

It has been suggested that a few reactors, with a designated hot cell facility, could be used to provide the full supply of the U.S. demand for Mo-99. The following evaluation specifically addresses the use of multiple TRIGA reactors but is generally applicable to all multiple reactor concepts.

The objective in the TRIGA option would be to irradiate targets in fuel locations throughout the core. This objective is virtually identical to the Annular Core Research Reactor alternative option of running

targets in fuel locations. TRIGA fuel and Mo-99 targets are approximately the same diameter (3.7 cm for TRIGA fuel and 3.2 cm for Mo-99 targets). For a typical 2-MW TRIGA reactor, the average fuel element power is approximately 20 kW, and target loading could be adjusted for target power. It is unclear what percentage of target power could be cooled by natural circulation in a fuel location. Further, target powers greater than average fuel element power may pose a licensing issue.

The replacement of TRIGA fuel with fissionable material that has no zirconium hydride (that is, a target) impacts the inherent safety mechanism of the TRIGA design. The zirconium hydride creates the strong negative temperature feedback mechanism characteristic with the TRIGA reactors. As fuel is replaced, the reactor dynamic parameters would be changed, and the licensing would be impacted. A conservative estimate would be that up to 10% of the fuel locations (10 targets replacing elements) could be used to contain Mo-99 targets. Licensing the TRIGA reactor with greater than 10% of the core power being generated from Mo-99 targets, which do not have the unique shutdown characteristics of TRIGA fuel, may pose a challenge.

The option of using two TRIGAs, with each having a power level of 2 MW to supply portions of the required demand, could be viable if they were in advantageous geographic locations. The best situation that was investigated is the Pacific Northwest where four small TRIGAs reside within several hours of one another. TRIGAs exist at Hanford in Richland, Washington; Washington State University at Pullman, Washington; Oregon State University in Corvallis, Oregon; and Reed College in Portland, Oregon. However, none of these reactors has a power level of 2 MW, and all would have to be upgraded.

This option would require that Mo-99 processing lines be established at two different facilities, or that irradiated targets be shipped from one (or both) reactors to a common processing facility. (The Hanford site has hot cell facilities that would be capable of performing the processing.) This procedure would either roughly double processing facility costs, or would necessitate routine shipment of freshly irradiated targets. Due to the time-sensitive nature of Mo-99 production, it is desirable to avoid having to ship irradiated targets by collocating the processing facility with the irradiation facility.

Also, it is important to maintain the capability of the facilities and personnel to produce 100% of the U.S. demand for Mo-99, if necessary. Therefore, under a two-reactor scenario, both reactors (and both processing facilities, if applicable) would have to be operated routinely in a standby mode. This arrangement would require that two full reactor staffs and facilities be maintained, which would increase the cost of the Mo-99 production capability.

This option would require the upgrade of several small reactors to 2 MW in a timely fashion, would require routine operation of two reactors, and would require either that significant shipping issues be addressed or that redundant processing capability be established. These activities would be costly and could not be achieved within the time frame specified in the evaluation criteria.

3.4.1.4 High Flux Isotope Reactor - Oak Ridge

The High Flux Isotope Reactor is a beryllium-reflected, light water cooled and moderated flux trap type 85 MW production and test reactor that uses highly enriched uranium fuel. The reactor core assembly is contained in an 2.4 m (8 ft) diameter pressure vessel located in a water-filled pool. The top of the pressure vessel is 5 m (17 ft) below the pool surface.

Typically, the High Flux Isotope Reactor operates continuously for 22 to 26 days at 85 MW followed by a 7- to 10-day outage for refueling and maintenance. In the past, unscheduled outages have also occurred, resulting in an on-stream time of approximately 65% over the past 2 years, which is not favorable to Mo-99 production. Also the primary mission of the High Flux Isotope Reactor is the production of transplutonic isotopes. The irradiation and experimental facilities that support this mission require steady state operation of the reactor for the longest possible period of time. Shutdown of the reactor (minimum of 3 days) to facilitate insertion and removal of the targets for Mo-99 production would be very disruptive to the primary missions. Long irradiation periods impact the quality of the molybdenum product due to specific activity arguments, as delineated in Section 3.4.1.1.

The High Flux Isotope Reactor alternative is rejected because its operating characteristics and its current primary mission will not allow it to meet the Mo-99 production facility selection criteria.

3.4.1.5 Bulk Shielding Reactor - Oak Ridge

The Bulk Shielding Reactor (BSR) has a forced cooling system and is capable of continuous operation at 2-MW power level. Operation of the BSR with low enriched uranium would be feasible. At full production capacity, 2330 6-day Ci of Mo-99 would be produced per week. The BSR could not meet the 3000 6-day Ci weekly Mo-99 production requirement specified in the selection criteria. The BSR could provide an estimated aggregate target power level of 380 kW. The requirement to meet the weekly U.S. demand is ≥ 490 kW continuously for 6 days. Because the BSR cannot meet the selection criteria specified in Section 3.1.1, it has been eliminated from detailed consideration.

3.4.1.6 Fast Flux Test Facility - Hanford

The Fast Flux Test Facility (FFTF) is a DOE reactor located on the Hanford Site, Richland, Washington. The reactor is a liquid sodium cooled, mixed oxide fast reactor. The initial criticality of the reactor occurred in 1980. The reactor is currently shut down. The reactor is rated at 400 MW and was designed to perform tests on fuels and components for liquid metal cooled reactors. In comparison, the reactor that Cintichem used to produce Mo-99 was a 5-MW reactor. The FFTF has many irradiation facilities.

The FFTF is located within a few miles of hot cell facilities adequate for Mo-99 target processing. The post irradiation Fuel Materials Examining Facility, which is adjacent to the FFTF, contains several banks of hot cells that were never completed due to loss of mission. Several other hot cell facilities with >100,000 curie ratings exist in the Hanford 300 area, approximately 8 km (5 mi) away.

The reactor operating cycle would preclude continuous Mo-99 production due to the required outage periods of a reactor of this size. Further, the FFTF is much too large to economically produce Mo-99. As a single mission for a facility that large, the rate of nuclear fuel utilization required to produce the neutrons for the Mo-99 production could not be reasonably justified. Therefore, the FFTF has been eliminated from detailed consideration.

3.4.1.7 Accelerator Facilities - Los Alamos and Others

Accelerators provide a means of accelerating charged particles such as electrons, protons, or deuterons to high energies. In a linear accelerator (LINAC), a beam of ions from an ion source is injected into an accelerating tube containing a number of coaxial cylindrical sections. Alternating sections are connected to a high-frequency alternating voltage from a high-powered oscillator. An ion traveling down the tube will be accelerated at a gap between electrodes, if the voltage is in the proper phase. Using a LINAC, electrons can be accelerated to several GeV and protons to about 600 MeV of energy. For proton acceleration to GeV levels, a device known as a cyclotron is used. In a cyclotron, a charged particle follows a circular path under the influence of an applied external magnetic field. Variations of cyclotrons are also known as a synchrotron, or an alternating gradient synchrotron. A number of radionuclides, including Mo-99 for use in medical applications, can be produced by bombarding a variety of targets with beams of particles from the accelerators.

This alternative explores the feasibility of using an accelerator to produce Mo-99, taking into consideration such factors as technical feasibility, time constraints, economic viability, and compliance with current federal regulations.

The accelerated charged particles, such as protons or deuterons, can be used to bombard a target to produce nuclear reactions. Accelerators can serve as a source of neutrons through intermediate charged particle reactions (known as spallation neutron reactions) leading to neutron emission. These neutrons, in turn, can cause nuclear reactions in a target or cause nuclear fission, if the target contains fissile material. Accelerators are used to produce a variety of isotopes for use in research, medical diagnosis and therapy, and industry. The following paragraphs describe a few state-of-the-art facilities producing isotopes in the U.S.

Built and commissioned in 1973, the Brookhaven LINAC Isotope Producer (BLIP) was one of the world's first facilities to demonstrate the capability of a large proton-LINAC for efficient medical radionuclide production by proton spallation of neutrons, as well as lower energy reactions. With its beam current of 50 μ A, a beam power of 100 kW, and a beam width of 1.9 cm (1.1 in.), BLIP successfully served as a workhorse for the production of medical isotopes for over two decades. This facility is planned

to be upgraded during 1996 to triple its beam characteristics. However, the quantity of various isotopes that could be produced even after the upgrade varies from a few μCi to a few Ci. This production capability would not meet the quantity and schedule requirements of the U.S. Mo-99 needs.

The Los Alamos Meson Physics Facility (LAMPF) at LANL has a proton LINAC with a beam current of 1 mA and power of 0.8 MW. It can accelerate protons to 800 MeV. The Isotope Production Facility at LAMPF has 13 shielded hot cells at its radiochemistry site at TA-18 that are fitted with remote manipulators.

The Isotope Production Facility at LAMPF currently produces several medical isotopes. Although LAMPF has a long record of producing isotopes, its capabilities are three orders of magnitude less than that required to produce 100% of the U.S. need for Mo-99.

Mo-99 can be produced using an accelerator through a variety of reactions on natural or enriched molybdenum or uranium including: Mo-98 (n,γ); Mo-98 (d,p); Mo-100 ($n,2n$); Mo-100 (γ,n); Mo-100 (p,pn); Mo-100 ($p,2p$); U-235 (n,f); and U-238 (p,f).

Consideration of the cross sections and reaction threshold energies for these reactions (DOE 1995c, and Andrade 1995) suggest that Mo-98 (n,γ), Mo-98 (d,p), Mo-100 (p,pn) and Mo-100 ($p,2p$) and U-238 (p,f) reactions are favored for the production of Mo-99 using accelerators. Approximately 9×10^{-5} Mo-99 atoms are reportedly produced per 15-MeV deuteron particle incident upon a Mo-98 target.

To produce 100% of U.S. weekly requirement of 3000 6-day Ci, requirements include a beam current of 740 mA of deuteron current and a beam power of about 11 MW, which are beyond the current state-of-the-art in accelerator technology.

One of the major problems in producing Mo-99 by using accelerators would be the state-of-the-art limitation in achieving heat transfer from the target. For example, Brookhaven National Laboratory currently produces copper-67 by irradiating a 5.7-cm-diameter x 0.79-cm-thick zirconium target. At the current beam current of 50 μA and beam power of 100 kW at the peak power density, the target at the beam center reaches temperatures as high as 541 °C. When the power level increases to 150 μA at the completion of the upgrades, the target temperature is projected to reach 990 °C. The target heating, during irradiation in an accelerator, is a significant problem even with beam currents on the order of a few hundred μA . Mo-99 production to meet 100% the U.S. demand would require operating at more than three orders of magnitude higher than the condition previously illustrated. Current state-of-the-art in accelerator physics precludes the possibility of producing this isotope on a commercial scale to adequately meet 100% of the present U.S. demand.

Work at the University of California-Davis, has created a novel approach of producing Mo-99 which consists of bombarding an enriched (>97%) Mo-100 target (5 g) with a 70-MeV negatively charged hydrogen ion dual beam with a total beam current of 400 μA . However, the expected specific activity of

Mo-99 would be only 48 Ci/g at the end-of-bombardment. This specific activity falls far short of the required specific activity of 10,000 Ci/g. In fact, all isotopes produced by nuclear transmutation have, in general, very low specific activity.

Mo-99 can be produced through (n, γ) reaction with Mo-98 using reactor-generated neutrons or using spallation neutrons derived from charged particle reactions. Published reports (Sameth and Hans 1987) suggest that specific activity of 1 to 10 Ci of Mo-99 are achievable using natural or 100% enriched Mo-98 targets, respectively. Theoretical calculations using thermal neutron flux of 10^{14} n/cm²-s yield specific activities of 0.6 Ci and 2.35 Ci with the natural molybdenum or 100% enriched Mo-98, respectively. Thermal neutron flux of about 4.3×10^{17} n/cm²-s would be needed to achieve the specific activity goal of 10,000 Ci/g of Mo-99. With the current state-of-the-art in nuclear technology, this goal would be unattainable using either spallation neutron sources or nuclear reactors.

In conclusion, using current technology accelerators for the production of Mo-99 in quantities sufficient to meet with the U.S. demand is neither technically feasible nor economically viable in the foreseeable future.

3.4.2 University Reactors

3.4.2.1 University of Missouri Research Reactor

The Missouri University Research Reactor operates a 10-MW light water moderated reactor. The reactor core consists of eight pie-shaped fuel elements that each contain 775 g of 93.5% enriched uranium-235 (University of Missouri 1994).

Mo-99 could be extracted from irradiated fuel from the Missouri University Research Reactor by a process similar to the one used by the AECL to produce raw Mo-99 for Nordion. The difference between these two processes is that AECL irradiates highly enriched uranium targets while the proposed Missouri process would use irradiated highly enriched uranium fuel.

At full production levels, a fresh fuel element could be added to the Missouri University Research Reactor core on a weekly basis. This fresh fuel element would be added during the normal reactor shutdown for refueling and maintenance. This process normally requires 4 to 8 h. Because of specific activity arguments presented in Section 3.4.1.1, processing of a spent fuel element would not yield a usable or marketable product. No additional waste would be produced at the Missouri University Research Reactor because of the Mo-99 production activities. However, waste would be generated at the Mo-99 separation facility.

The three scenarios that were evaluated for processing of the Missouri University Research Reactor fuel elements are summarized as follows:

- The Missouri University Research Reactor fuel would be shipped to AECL for initial processing by a method similar to the one currently used to process targets for Nordion.
- The Missouri University Research Reactor fuel would be shipped to one of the DOE national laboratories at Argonne, Oak Ridge, Hanford, Idaho Falls, or Los Alamos for processing by the method used by AECL to remove the raw Mo-99. The raw molybdenum would be shipped to Nordion for purification and distribution to the radiopharmaceutical companies.
- The Missouri University Research Reactor fuel would be shipped to one of the DOE national laboratories and processed to remove the Mo-99, purified, and distributed directly to the radiopharmaceutical companies within the U.S.

The proposed University of Missouri option would supply a single amount of Mo-99 to the radiopharmaceutical houses only once a week. The medical community uses the product on a near continuous basis, and receives Tc-99m generators from the radiopharmaceutical companies every weekday. This periodicity has been long established by the ultimate users, the physicians performing the procedures. A change to this periodic process is not impossible but would be extremely impractical. The user, not the supplier, will almost certainly determine the demand frequency.

In addition to acquiring access to the Nordion proprietary process, the Missouri University Research Reactor option would require that hot cells rated at approximately 400,000 Ci of 1-MeV gamma be constructed at the reactor site to process a freshly irradiated fuel element. The process would be functional but very waste intensive. Without the substantial hot cells, the option would not be acceptable. The analysis of this position follows.

Shipping a fresh fuel element after a 7-day irradiation period has at least two associated problems. One is with regard to specific activity. The other is with regard to shipping significant quantities of halogens and noble gases. For assessment purposes, assume that all fuel elements operate at the same power level of 1.2 MW each. This value is not a conservative one, in that a fresh fuel element would probably produce 10 to 20% more power than a fuel element having several cycles of exposure. The product from a 1.2 MW fuel element would be approximately 48,000 Ci of Mo-99 with a specific activity of about 75,000 Ci per gram.

The best cask currently designed for this type of shipment would be the BMI-1 cask. Maximum decay heat generation from material contained in this cask would be 1.5 kW. Using General Electric decay heat curves for light water reactors and an irradiation period of 7 days, greater than 62 h would be required for a 1.2-MW fuel element to cool to 1.5 kW. The international standard on decay heat calculation (INS 10645) confirms this result. At least two dedicated BMI-I casks would be required for this effort.

If the cask were loaded and the truck surveyed and released within 3 h, about 65 h would have passed since release of the fuel element from the reactor. Remaining in the fuel element would be 72% of the xenon-133, 79% of the iodine-131, 13% of the iodine-133, and all the krypton-85. This situation is an

unusual one with exception of the krypton-85, which has a very low (0.3%) fission yield. Shipment of spent fuel usually requires 180 days of cooling to ensure that noble gases and halogens have decayed. This unusual situation is a licensing challenge, but it is probably not insurmountable.

Shipping to the nearest suitable hot cell would require transportation of the fuel element to Los Alamos, approximately 20 h distance by truck. Processing of the fuel element would commence approximately 87 h after removal of the fuel element from the reactor, assuming a 2-h truck and cask unloading period. Assuming the processing, packaging, and shipment would require an additional 16 h, the product would reach the radiopharmaceutical houses approximately 103 h after irradiation. The total activity at this time is approximately 16,250 Ci with a specific activity of 25,500 Ci per gram. The product falls below the required specific activity levels in 88 more hours, or less than 4 days. Further, delivering approximately 2750 actual Ci per day, plus radioactive decay, would deplete the lump quantity extracted from the fuel element in 3 days. No deliveries would be made during the fourth and fifth days of the weekly cycle, as the ultimate user requires.

The other two general options considered involve similar shipping delay times, and would be unacceptable for the same reasons. Additionally, AECL is opposed to the first option because of liquid waste storage constraints at the AECL facility.

Mo-99 recovery from the Missouri University Research Reactor fuel elements would entail two other disadvantages, applicable to all Missouri University Research Reactor options. First, this alternative would involve the dissolution of highly enriched uranium reactor fuel and require continued operation of the reactor with highly enriched uranium fuel. DOE does not encourage the civilian use of highly enriched uranium, and has a program to convert highly enriched uranium-fueled research reactors to low enriched uranium fuel. The selection of this alternative would make DOE dependent on the highly enriched uranium fuel in the Missouri University Research Reactor for the production of Mo-99. Second, the processing activities are more waste intensive than a target type system. The fuel element, including cladding, must be dissolved to extract the product. Machines could probably be designed to cut the upper and lower unfueled sections from the fuel element. Milling the sides to free all the plates could also be performed by some machinery. Even with these improvements, virtually all the cladding, plus extra material, must be dissolved with the fuel. This process generates significantly more radioactive waste than the target process, in which only a thin layer of uranium is dissolved.

For the reasons stated, it was determined the Missouri University Research Reactor fuel processing option, as currently configured, does not meet the screening criteria and the alternative was dismissed from further consideration.

3.4.2.2 Other University Reactors

In addition to the Missouri University Research Reactor, a number of other research reactors operated by domestic universities were considered for the Mo-99 production project. These reactors were dismissed as reasonable alternatives for the following reasons:

- Most of the reactors operated by the universities are rated at less than 2 MW power and were individually too small for the U.S. Mo-99 production requirements.
- Very few of the university reactors have adjacent hot cells facilities that could accommodate the Mo-99 extraction activities of a full U.S. demand production rate. Lack of hot cells would require shipment of the irradiated targets to another location for processing or the construction of new facilities.
- Many university reactors do not have an operational history that was deemed reliable for Mo-99 production.
- Most of the university reactors have other missions (such as, research and education) and simply are not available for dedication to the Mo-99 production program.

3.4.3 Other Public/Private Options

The DOE has taken the position that, in the long-term, production of Mo-99 in the U.S. should be conducted by the private sector. Therefore, DOE encourages the development of private sources in the U.S. for the production of Mo-99 and would phase-out DOE production as a private source(s) begins reliably producing Mo-99. However, each of the options identified following does not represent a viable near-term option for the production of Mo-99, and these options are not considered to be reasonable alternatives to satisfy the purpose of and need for the proposed action.

3.4.3.1 Isotopes U.S.A.

A proposal submitted to the DOE in October 1994 by personnel from DOE's INEL and the University of Idaho outlined a concept referred to as Isotopes U.S.A. The proposal described the creation of a not-for-profit corporation dedicated to education, research, and other scientific purposes relevant to the production and use of stable and radioactive isotopes.

As proposed, Isotopes U.S.A. would oversee and direct isotope production and distribution, isotopes research, education and training, administration, and not-for-profit isotope ventures. Isotopes U.S.A. proposes to use existing DOE facilities for the production and distribution of radioisotopes, including Mo-99; however, no specific DOE facility has been identified.

The Isotopes U.S.A. concept offers a possible vehicle to facilitate the privatization of isotope production activities in the U.S. However, because the concept is based on utilizing existing DOE irradiation and processing facilities, it does not offer any advantage or expediency to the near-term development of a domestic backup source for Mo-99. It was dismissed as a reasonable alternative because it is a management, not a production, concept.

3.4.3.2 Babcock and Wilcox Medical Isotope Production Reactor

The Medical Isotope Production Reactor (MIPR) concept developed by Babcock & Wilcox would use an aqueous solution of uranyl nitrate contained in an aluminum or stainless steel vessel immersed in a large pool of water that can provide shielding and a medium of heat exchange. This concept would use a liquid-fueled reactor to produce Mo-99, and it may offer some advantages over the Cintichem process, especially in the area of waste minimization. However, the concept is still at the conceptual design and feasibility demonstration stage and does not represent a reasonable near-term production source for Mo-99. Therefore, it was dismissed from further consideration.

3.4.3.3 Thermo Technology Ventures, Inc.

Thermo Technology Ventures, Inc., is in the process of evaluating an alternative production method for Tc-99m, the daughter product of Mo-99. This production method would use small linear accelerators to directly produce Tc-99m. These accelerators would be located at or near medical facilities, which would greatly simplify handling and transportation of the Tc-99m. However, the concept is still at the conceptual design and feasibility demonstration stage, and does not represent a reasonable near-term production source of Mo-99.

Accelerator-based production of Tc-99m is technically feasible, as explained in Section 3.4.1.7. This small accelerator concept does not involve the use of highly enriched uranium, and may offer other improvements over current Mo-99/Tc-99m production methods, especially in the area of radioactive waste generation. However, to be able to supply 100% of the U.S. demand for Tc-99m, many of these small accelerators would have to be built. Thermo Technology Ventures plans to accomplish this goal with about 20 accelerator centers. The Thermo Technology Ventures concept is currently in the conceptual design and feasibility stage, but plans are to complete technology development by the end of 1996. While Thermo Technology Ventures plans to initiate operations in 1997, they estimate that implementation to supply the entire U.S. demand for Mo-99 could not be completed until December 1999. Therefore, the concept does not represent a near-term option to satisfy the purpose of and need for the proposed action. However, as mentioned earlier, DOE could phase out production of Mo-99 at such time as this or any other private source begins producing Mo-99 reliably.

3.5 Comparison of Alternatives

The tables at the end of this section comparatively summarize the reasonable alternatives analyzed in this FEIS in terms of their expected environmental impacts and other factors. Table 3-1 compares the environmental impacts of the alternatives, as discussed in detail in Section 5. Table 3-2 compares other aspects of the reasonable alternatives, such as facility operating parameters, estimated schedule, and other factors.

Table 3-1. Summary of Environmental Consequences and Comparison of Alternative

Consequence Category	Unit of Measure	Alternatives			
		SNL/NM-ACRR LANL/CMR	LANL OWR/CMR	ORNL ORRR/RDL	INEL PBF/TAN
Air Quality					
Dose from Radionuclide Emissions to Air (normal operations)					
Onsite Collocated Worker	mrem/yr				
Target Irradiation		0.00011	0.012	0.00036	0.0013
Target Processing		0.037	0.00015	0.022	0.29
Offsite Maximally Exposed Individual	mrem/yr				
Target Irradiation		0.00017	0.15	0.0040	0.0013
Target Processing		0.17	0.0042	0.31	0.13
Population Within 80 km (50 mi)	person-rem/yr				
Target Irradiation		0.023	0.63	0.41	0.011
Target Processing		13.0	0.032	15.	1.2
Risk of Latent Fatal Cancer ^(a)		0.007	0.0003	0.008	0.0006
Occupational Health and Safety					
Radiological Dose to Project Workers	person-rem/yr	22-25	9-12		
Risk of Latent Fatal Cancer ^(a)	-	0.01	0.005	(b)	(b)
Industrial Accidents-Illnesses and Injuries					
Construction	total incidence	6	6	7	6
Operations	annual incidence	2	1	2	2
Transportation					
Incident Free Transport (Annual Shipments of Targets, Products, and Waste)					
Radiological Dose	person-rem/yr	Total			
Crew		76 24	75 23	49 23	76 23
Public		52	52	26	53
Risk of Latent Fatal Cancer ^(a)	-				
Crew		0.01	0.01	0.01	0.01
Public		0.03	0.03	0.01	0.03
Nonradiological Consequences					
Risk of Latent Fatal Cancer from Vehicle Emissions ^(a)		0.009	0.008	0.009	0.008

Table 3-1. (contd)

Consequence Category	Unit of Measure	Alternatives			
		SNL/NM-ACRR LANL/CMR	LANL OWR/CMR	ORNL ORRR/RDL	INEL PBF/TAN
Transportation Accidents (Ground and Air)					
Dose to Maximally Exposed Individual at 100 m (If accident occurs):	rem		Similar for all alternatives		
Unirradiated Targets		0.91			
Irradiated Targets		1.3			
Separated Mo-99		0.62			
Separated I-125		0.054			
Separated I-131		2.6			
Separated Xe-133		0.063			
Low-Level Waste		1.4x10 ⁻⁶			
Collective Public Risk from Transportation Accidents Involving Radioactive Materials					
Risk of Latent Fatal Cancer ^(a)	-	2 x 10 ⁻⁵	2 x 10 ⁻⁵	1 x 10 ⁻⁵	2 x 10 ⁻⁵
Vehicle Accident Fatalities	-	0.01	0.01	0.02	0.01
Highest Consequence Facility Accidents					
Target Irradiation		Multiple Fuel Element Rupture	Fuel Melt	Fuel Melt	Fuel Melt
Accident Frequency	events/yr	5 x 10 ⁻⁵	10 ⁻⁶ to 10 ⁻⁴	10 ⁻⁶ to 10 ⁻⁴	10 ⁻⁶ to 10 ⁻⁴
Dose to Offsite Maximally Exposed Individual Inhalation/External ^(c)	rem	0.076	0.48	0.037	0.099
All Pathways ^(c)		0.20	5.7	0.42	1.6
Dose to Population Within 80 km (50 mi) Inhalation/External ^(c)	person-rem				
All Pathways ^(c)		150-2300 151-2350	91-930 91-940	750-1400 5400-11000	20-170 900-7300
Latent Fatal Cancers (if accident occurs)	-	≤1	<1	<1 - 6	<1 - 4
Risk of Latent Fatal Cancer ^(a)		4 x 10 ⁻⁶ to 6 x 10 ⁻⁶	5 x 10 ⁻⁶	7 x 10 ⁻⁶ to 3 x 10 ⁻⁴	9 x 10 ⁻⁷ to 4 x 10 ⁻⁵
Target Processing		Mo-99 Target Process (Operator error)	Mo-99 Target Process (Operator error)	Mo-99 Target Process (Operator error)	I-125 Target Process (Operator error)
Accident Frequency	events/yr	1.0	1.0	1.0	0.1
Dose to Offsite Maximally Exposed Individual Inhalation/External ^(c)	rem				
All Pathways ^(c)		7.4 x 10 ⁻⁴ 7.4 x 10 ⁻⁴	8.9 x 10 ⁻³ 8.9 x 10 ⁻³	1.3 x 10 ⁻⁴ 1.3 x 10 ⁻⁴	3.1 x 10 ⁻⁵ 5.9 x 10 ⁻³

Table 3.1. (contd)

Consequence Category	Unit of Measure	Alternatives			
		SNL/NM-ACRR LANL/CMR	LANL OWR/CMR	ORNL ORRR/RDL	INEL PBF/TAN
Dose to Population Within 80 km (50 mi)	person-rem				
Inhalation/External ^(c)		2.6 - 32.	1.8 - 10.	2.5 - 4.8	0.0062 - 0.40
All Pathways ^(d)		2.6 - 32.	1.8 - 10.	2.5 - 4.8	0.38 - 1.2
Latent Fatal Cancers (If accident occurs)	-	<1	<1	<1	<1
Risk of Latent Fatal Cancer ^(a)		1 x 10 ⁻³ to 2 x 10 ⁻³	5 x 10 ⁻⁴ to 9 x 10 ⁻⁴	2 x 10 ⁻⁴ to 1 x 10 ⁻³	3 x 10 ⁻⁷ to 2 x 10 ⁻⁵
Resource Use - Construction					
Electricity	kilowatt-h	230	negligible	4	450
Concrete	cubic meters	1200	0	20	2400
Constructon Steel	tonnes	0.21	0	negligible	0.39
Stainless Steel	tonnes	1.0	0.2	3.5	1.5
Resource Use - Operation					
Water	1000 m³/yr	40	120	120	120
Electricity	megawatt-h/yr	400	500	500	500
Materials - Target Fabrication HEU	kg/yr	4-36 ^(d)	3 ^(d)	3-26 ^(d)	3-26 ^(d)
Stainless Steel	tonnes/yr	0.50	0.36	0.36	0.36
Chemicals - Isotope Recovery				Same as LANL	
Sulfuric acid, 2N	liters	(e)	120		
Sulfuric acid, 0.1N	liters		36		
Hydrochloric acid, Reagent grade	liters		1.2		
Nitric acid, reagent grade	liters		6		
Sodium hydroxide, 0.2N	liters		24		
Sodium iodide	grams		120		
Silver Nitrate	grams		600		
Benzoin-α-oxine	kilograms		2.4		
Molybdenum trioxide	grams		24		
Potassium permanganate	grams		100		
Rhodium trichloride	grams		24		
Potassium hexachlororuthenate	grams		24		
Hydrogen peroxide	liters		2.4		
Calcium oxide	liters		12		
Calcium sulfate "drierite"	liters		36		
Molecular sieve type 13X	liters		36		
Reactor Fuel					
Kilograms of uranium used in fuel	kilograms U/yr	16	32	32	32

Table 3.1. (contd)

Consequence Category	Unit of Measure	Alternatives			
		SNL/NM-ACRR LANL/CMR	LANL OWR/CMR	ORNL ORRR/RDL	INEL PBF/TAN
Operational Wastes					
Low-Level Radioactive Liquid	cubic meters/yr	7.3 ^(f)	5.2 ^(f)	5.2 ^(f)	5.2
Low-Level Radioactive Solid	cubic meters/yr	49	17.6	68	80
Socioeconomics					
Primary Employment					
Construction/Modifications	worker-years	92	92	113	97
Routine Operations	workers	59	45	62	59
Costs					
Construction/Modifications	million dollars	19.6	19.6	21.0 ^(g)	17.2
Routine Operations	million dollars	12.8	11.0	9.6 ^(g)	8.4 ^(g)
(a) Radiological risk from normal operations or accidents is calculated as the latent cancer fatalities that might result if a radiological exposure occurred, multiplied by the estimated frequency of the event. The risk for normal operation assumes a frequency of 1.0 (i.e., the exposure is assumed to occur), whereas the risk for accidents is estimated using the combined frequency of the accident and the assumed atmospheric conditions (if applicable) for a particular accident scenario. Where the risk of latent fatal cancer is less than 1, no cancers would be expected to result from a year of operation.					
(b) Operational doses for ORNL and INEL are assumed to fall within the range of those estimated for SNL and LANL.					
(c) Accident consequences are conservative estimates that assume no protective actions are taken for offsite members of the public. The "Inhalation/External" pathway results correspond to a hypothetical release during a season when no agricultural products for human or animal consumption are growing. The "All Pathways" results correspond to a hypothetical release just before harvest, thereby maximizing the potential consequences of ingesting contaminated food. Neither analysis assumes protective action such as evacuation, sheltering, or interdiction of contaminated food products for the public.					
(d) Minimum values assume 90% recovery of HEU after isotope extraction. Uranium recovery would occur at LANL, and could be implemented at other sites. However, consequence analyses presented in Section 5 do not assume uranium recovery at other sites other than LANL.					
(e) Consumption of chemicals for target processing assumes irradiation of targets to a power of 20 kW. At SNL/NM, production rates corresponding to 100% replacement of U.S. needs would likely require processing of a greater number of targets at lower power. In that case, the quantity of chemicals used to process the targets would increase by about 40%.					
(f) Liquid waste volume is before solidification. Liquid wastes would be solidified at indicated sites prior to disposal. ACRR - Annular Core Research Reactor; CMR - Chemistry and Metallurgy Research Facility; ORRR - Oak Ridge Research Reactor; OWR - Omega West Reactor; RDL - Radioisotope Development Laboratory; TRA - Test Reactor Area.					
(g) As explained in Section 5.22, the cost estimates for ORNL and INEL are expected to contain greater than those presented for SNL/NM and LANL.					

Table 3-2. Comparison of Alternatives for Mo-99 Production at 100% Production

Comparison Category	Unit of Measure	Alternatives			
		SNL/NM-ACRR LANL-CMR	LANL OWR/CMR	ORNL ORRR/RDL	INEL PBF/TAN
Reactor Parameters					
Reactor Power	MW	Approx. 3 MW	8	10	8
Neutron Flux	n/cm ² -s	8x10 ¹⁵	1x10 ¹⁴	4x10 ¹³	3.7x10 ¹³
Reactor and Target Cooling		Natural convection	Forced convection (Natural convection ≤ 0.5 MW)	Forced convection	Forced convection
Fuel Utilization	1.052 gms U-235 per MWD for all sites	56 TRIGA elements/yr (3.73 cm dia, 75 cm long)	29 fuel elements/yr (7.6 x 7.7cm x 86 cm)	36 fuel elements/yr (slightly larger than OWR)	19 bundles/yr (14.7 cm x 14.7 cm x 80 cm)
Spent Nuclear Fuel Storage Capacity	elements	300 elements current capacity. Expansion to 1000 elements possible through installation of additional spent nuclear fuel racks.	1091 elements	984 elements	786 bundles
Current Status		Operational	Shut down	Shut down	Standby
Target Power Level	kW				
No. of Irradiation Targets Possible		19 at 21 kW at partial production 37 at 16 kW at full production	16 (1st phase) 36 (2nd phase)	Up to 40, to be minimized	19
Target Transport		Short distance (hundreds of ft) closed but unsealed cask	Four miles, sealed casks	Short distance (hundreds of ft) sealed cask	Several miles, sealed cask
Hot Cells After Irradiation		Current hot cells at SNL/NM about 2,000 Ci @ 1 MeV, 5 bays, not completely segregated, would only be used for testing/startup and some initial production. New hot cells required for full production. Planned for 100,000 Ci @ 1 MeV, 1 cell, 5 segregated bays. Upgrade to hot cell ventilation reqd for operation. Current is single-train, single-stage filtration. Planned for single-state series parallel HEPA and charcoal bed.	No major modifications needed. 16 cells, 100,000 Ci, 2 small cells at each end for packaging. Series-parallel ventilation as follows: HEPA-charcoal bed-HEPA-Holdup volume-two-stage charcoal beds-two-stage HEPA.	No major modifications needed. 4 cells, 100,000 Ci. Series-parallel ventilation, single-stage HEPA and charcoal beds.	Cells are adequate, but would require minor modifications. Test Area North has 4 cells, 100,000 Ci, series parallel ventilation.
Schedule (from date of record of decision)		6 months from ROD to initial production 28 months from ROD to full production.	13 months from ROD to initial production 20 months from ROD to full production	24 months from ROD to initial production 30 months from ROD to full production	22 months from ROD to initial production 28 months from ROD to full production

Table 3-2. (contd)

Comparison Category	Unit of Measure	Alternatives			
		SNL/NM-ACRR LANL-CMR	LANL OWR/CMR	ORNL ORRR/RDL	INEL PBF/TAN
Waste Management		Low-level waste stored onsite until shipment for disposal at Nevada Test Site. Liquids solidified.	Cradle-to-grave waste management. No shipping, all waste disposed at LANL facilities. Solid waste crusher minimizes volume. Liquids solidified.	Low-level waste stored onsite until shipment for disposal at Nevada Test Site. Liquids solidification.	Cradle-to-grave waste management. No shipping, all waste disposed at INEL facilities. Liquid low-level waste treated and stored onsite.
Isotope Production History on Site		None	50 years isotope production experience. 20 years medical isotope production experience. Received FDA official certification of "Drug Establishment" in August 1991.	50 years isotope production experience. 50 years medical isotope production experience. Received FDA official certification of "Drug Establishment" in August 1991.	35 years isotope production experience.
Other Issues		DOE Preferred Alternative. Must maintain ACRR to be available to DOE Defense Programs to utilize in times of national emergency to address national security concerns.	Many redundant hot cells for online backup. Target fabrication process developed and in place at LANL. Uranium recovery from target wastes established from previous programs.		PBF lease agreement in place Idaho Brain Tumor Center for Boron Neutron Capture Therapy. Idaho Brain Tumor Center interested in shared cost venture.
ACRR - Annular Core Research Reactor; CMR - Chemistry and Metallurgy Research Facility; ORRR - Oak Ridge Research Reactor; OWR - Omega West Reactor; RDL - Radioisotope Development Laboratory; PBF - Power Burst Facility; TAN - Test Area North; ROD - record of decision.					

4.0 Affected Environment

This section describes the affected environment at each of the alternative sites being considered for the production of molybdenum-99 (Mo-99). Aspects of the affected environment discussed include land use, socioeconomic environment, cultural resources, aesthetic and scenic resources, geologic resources, air quality, water quality, ecological resources, noise, transportation, occupational and public health and safety, site services, and waste management.

For the reader's convenience, discussion of each of the four alternative sites begins with an overview of the site. Further detail is then provided in subsequent sections where such detail is necessary or appropriate for explaining environmental impacts. Additional descriptive information for each site can be found in referenced source documents.

4.1 Sandia National Laboratories—Albuquerque

4.1.1 Overview

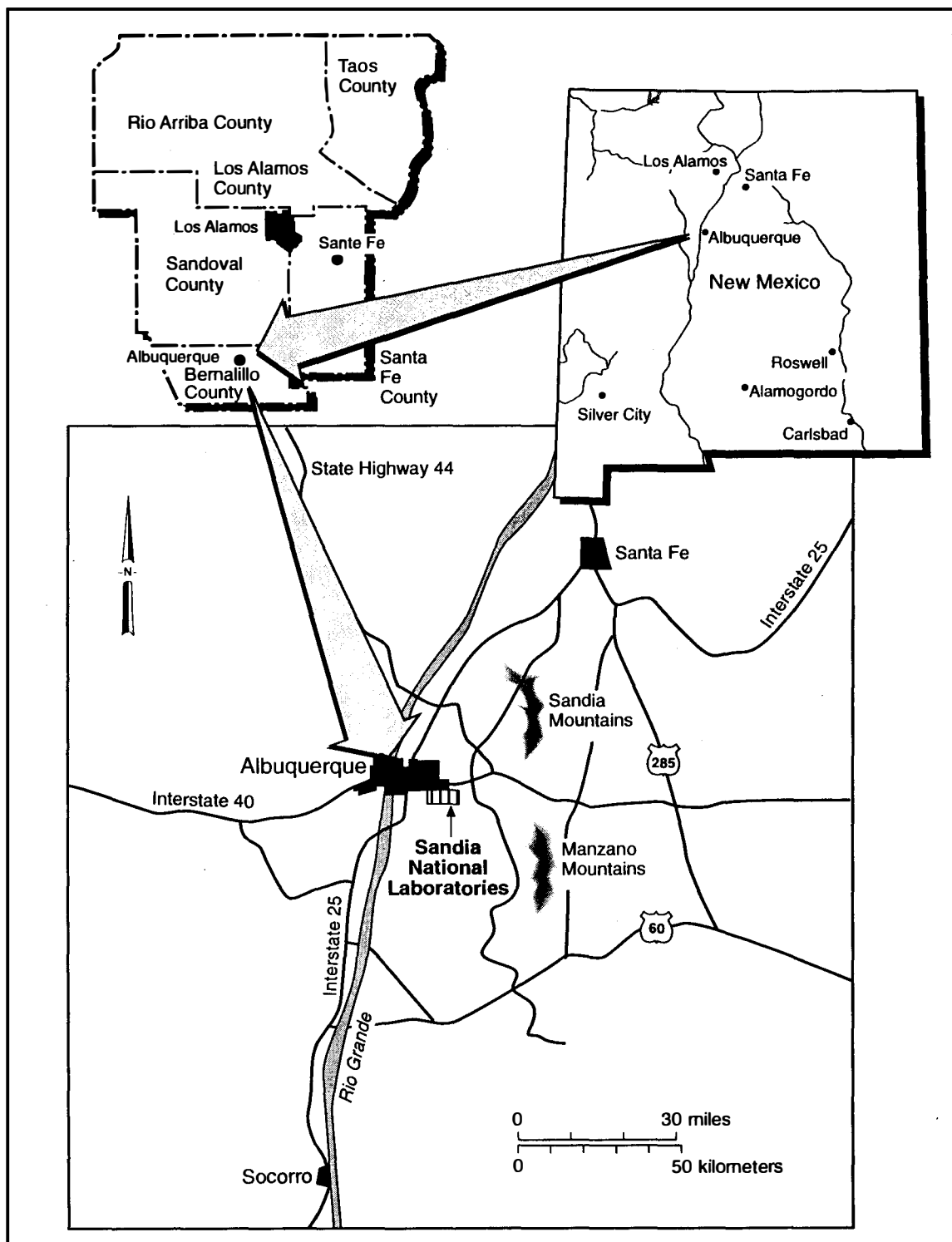
This overview section describes the affected environment for the Annular Core Research Reactor and associated hot cell facilities that are located in Technical Area V within Sandia National Laboratories/New Mexico (SNL/NM) on Kirtland Air Force Base in Albuquerque, New Mexico.

The city of Albuquerque is located in Bernalillo County in north-central New Mexico (Figure 4-1). The Sandia Mountains rise steeply immediately north and east of the city, and the Manzano Mountains are to the southeast. The Rio Grande runs southward through Albuquerque and is the major river traversing central New Mexico.

Major transportation services are provided by the Albuquerque International Airport and interstate highways I-40 and I-25. Other significant regional highways include U.S. 60 and U.S. 285.

The closest Native American population is about 13 km (8 mi) southwest of the Annular Core Research Reactor site. All other areas within a radius of 6.0 km (3.7 mi) are under the control of SNL/NM, except a small area immediately east of SNL/NM, which is within the Albuquerque city limits. The Annular Core Research Reactor is an existing facility within a developed area, and no archaeological or Native American resource properties would be affected by use or upgrade of this reactor. The facility is unlikely to be eligible for inclusion on the National Register of Historic Places.

Seismically, the Albuquerque area is characterized as a region of high activity but relatively low magnitude and intensity. Statistical studies show that a nondamaging earthquake (Modified Mercalli Intensity less than III) may be expected every 2 years, with a damaging event every 100 years.



SG95110116.15

Figure 4-1. Location of Albuquerque, New Mexico and Surrounding Areas

The total 1993 population dose within an 80-km (50-mi) radius surrounding SNL/NM was calculated to be 0.027 person-rem from SNL/NM operations, compared with 57,000 person-rem from external exposure to natural background radiation. Current operation of the Annular Core Research Reactor releases approximately 218 Ci/yr of argon-41. The dose calculated for maximum capacity is less than 0.1 mrem/yr to the maximally exposed individual at the KAFB.

The SNL/NM produces low-level radioactive and low-level mixed waste. These wastes are generated at SNL/NM in technical and remote test areas as the result of research, development, and technology activities. Low-level mixed wastes at SNL/NM include radioactively contaminated oils and solvents, radioactively contaminated or activated lead, or other heavy metals.

4.1.2 Land Use

4.1.2.1 Albuquerque Area

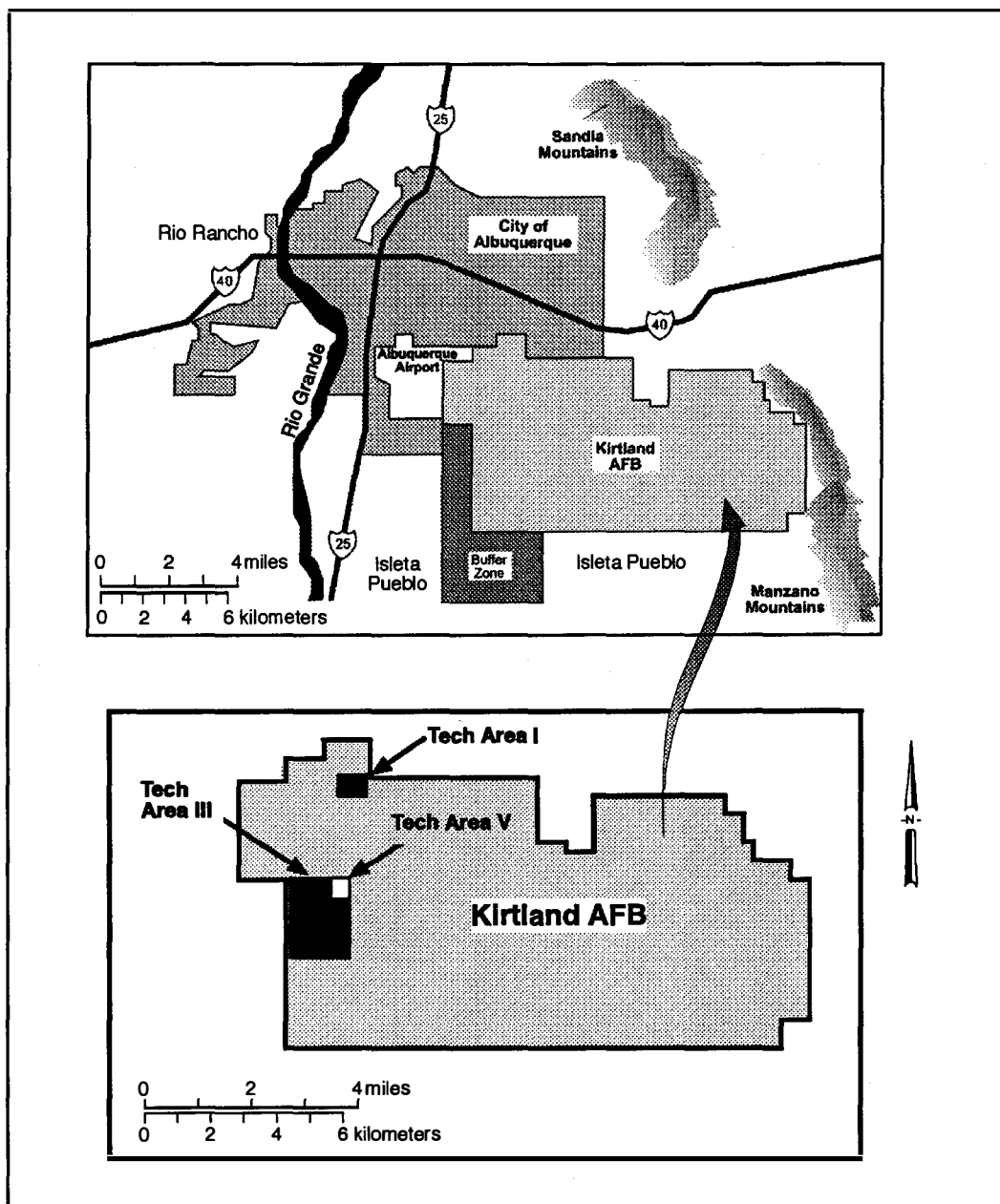
The Albuquerque metropolitan area is divided into quadrants, with the city occupying all land from the southwest quadrant clockwise through the northeast quadrant. Resources and facilities within Albuquerque include the University of New Mexico and other post-secondary schools, numerous shopping and residential areas, several museums, and recreational areas along the Rio Grande and within the nearby mountains. Major transportation services are provided by the Albuquerque International Airport and Interstates 40 and 25. Adjacent to the city, in the southeast quadrant, is KAFB, which includes the SNL/NM. KAFB shares runways and other flight facilities with the Albuquerque International Airport. Nearby communities include Rio Rancho and Corrales to the northwest, Sandia Pueblo to the north, and Isleta Pueblo, Los Lunas, and Belen to the south.

4.1.2.2 Sandia National Laboratories

The SNL/NM is located on DOE-owned land within the KAFB installation (Figure 4-2) and covers approximately 210 km² (81 mi²). The SNL/NM facilities occupy about 96 km² (37 mi²), of which 11.3 km² (4.4 mi²) are DOE-owned land.

Research activities at SNL/NM are organized by function and are centered within one or more of the five technical areas and one test area that have been established. These areas and uses are

- Technical Area I: Administration, site support, technical support, component development, research, energy programs, microelectronics, defense programs, and exploratory systems.
- Technical Area II: Testing of explosive components. See figures in Section 4.1.11.1.



SG95110116.2

Figure 4-2. Location of Technical Areas Within KAFB and Sandia National Laboratories

- Technical Area IV: Applied pulsed-power sciences, such as x-ray, gamma-ray, and particle-beam fusion accelerators that are used to simulate nuclear weapon effects; research on inertial-confinement fusion and particle-beam weapons. See figures in Section 4.1.11.1.
- Technical Area V: Research and testing of various materials, such as electronics, in a nuclear environment provided by low-power nuclear reactors. The Annular Core Research Reactor and associated hot cells are located within this area.
- Coyote Test Field: Various test activities on land parcels scattered throughout Coyote Test Field. These parcels are on 1- to 5-year land-use permits from the U.S. Air Force.

4.1.2.3 Technical Area V

Technical Area V, which contains the Annular Core Research Reactor, slopes toward the Rio Grande and is situated on a slight ridge that has numerous small canyons (arroyos). One arroyo of significance, Arroyo del Coyote, is about 0.8 km (0.5 mi) east of the complex, running southeast to northwest and emptying into Tijeras Arroyo. About 3 km (1.9 mi) to the north of Technical Area V, the topography is dominated by Tijeras Canyon. Routine access to the Technical Area V complex is provided by a paved road from Pennsylvania Street. Normal access to the area can be restricted. The shortest distance between the city limits and the Technical Area V complex is about 2 km (1.2 mi) (Massey and Coats 1995).

4.1.3 Socioeconomic Environment

4.1.3.1 Demographic Characteristics

The population center of major concern is metropolitan Albuquerque. The 1993 U.S. Department of Commerce figures indicate 506,700 people live in Bernalillo County. The majority of the population in the county is white, accounting for 76.8% of the total, with 3.4% Native Americans, 2.8% Black, 1.6% Asian, and 15.4% various other origins. People of Hispanic origin of all races account for 37.1% of the total population. Approximately 63% of the population is between 18 and 65 years of age, while 26% is under 18 years of age. Over 80% of the population has a high school education, and 26% has a college degree.

The 1990 median household income for Bernalillo County was \$27,382 and 1990 per capita income was \$19,854. The county's median household income is just below the state average of \$27,623. Approximately 10.9% of the total number of families in Bernalillo County lived under the poverty line at the time of the 1990 census.

4.1.3.2 Economic Base

The SNL/NM is located in a major metropolitan area surrounded by a local economy that has generated an increasingly higher level of personal income. Total personal income has grown by 22.7%

from 1990 to 1993 to a total annual of \$10.06 billion. By far, the largest contributor to personal income has been the services industry, accounting for 28% of the total, followed by government and government enterprises at 17%. The rest of the sectors of the economy are below the 10% level. During the same period, significant growth was experienced by various other sectors. For example, in 1993 the mining industry generated \$7.2 million dollars, which represented a 58% increase over its 1990 level. At the same time, the construction, services, and retail trade sectors experienced growth rates greater than 25%.

The private sector accounts for 63% of total income generated; the remaining 37% comes from the federal civilian, military, government and government enterprises, and state and local government sectors. Within the governmental sectors, the largest contributor is government and government enterprises with 50% of this share.

Total 1993 employment in Bernalillo County was estimated at 336,688 jobs, representing an average growth of 7% from 1990. SNL/NM is a major source of employment in Bernalillo County. In 1993, of the total labor force employed in Bernalillo County, 86% were salaried employees. The services industry was the largest employer, accounting for 33% of the total (see Table 4-1). Total unemployment was recorded at 5.2% in 1991.

Table 4-1. Employment by Major Industry for Bernalillo County
(number of jobs)

Sector	1990	1993
Agriculture, Forestry, Fishery Services	1,902	2,064
Mining	1,180	1,074
Construction	16,688	19,461
Manufacturing	22,990	23,676
Transportation and Public Utilities	13,842	13,852
Wholesale Trade	15,999	17,033
Retail Trade	54,832	58,999
Finance, Insurance, and Real Estate	24,885	24,477
Services	100,517	112,283
Government and Government Enterprises	61,428	63,081
Federal, Civilian	14,087	14,489
Military	7,567	7,200
State and Local	39,774	41,392
(a) Source: DOC 1994d.		

4.1.4 Cultural Resources

Because the Annular Core Research Reactor is an existing facility in a greatly modified landscape, no archaeological or Native American resource properties would be affected by the upgrade or use of this reactor. The facility itself was originally constructed in 1967 and now houses a second-generation reactor that replaced a predecessor. Because of a lack of the original integrity and its relatively recent vintage, the facility is an unlikely candidate for inclusion on the National Register of Historic Places.

4.1.5 Aesthetic and Scenic Resources

The topography of the Albuquerque area and the proximity of the Sandia and Manzano mountains afford a nearly unrestricted view of mountain scenery from Albuquerque. The view to the south from the city consists partially of KAFB, Albuquerque International Airport, and SNL/NM facilities, as well as some open rangeland. Development of the U.S. Air Force and SNL/NM facilities has had a significant impact on the landscape south of Albuquerque.

4.1.6 Geologic Resources

This section summarizes the physiography, geology, and seismic hazards at the SNL/NM. A more detailed summary of these subjects can be found in SNLA (1993a).

4.1.6.1 General Geology

Physiography. The SNL/NM is contained entirely within the boundaries of the KAFB. The KAFB is located on the eastern edge of the Albuquerque-Belen Basin, one of the largest of a series of north-south aligned basins in the Rio Grande trough (Figure 4-3). Elevations range from 1500 m (4920 ft) at the Rio Grande River to 2435 m (7988 ft) at the Manzano Lookout Tower in the Manzano Mountains. The western two-thirds of the area is relatively flat, sloping gently westward toward the Rio Grande.

Geology. A detailed description of the geology of this area is found in SNLA (1990, 1993a).

Structure. SNL/NM and KAFB lie directly over the intersection of several major faults along the eastern boundary of the Albuquerque-Belen Basin (SNLA 1993c). These fault systems include the Manzano, Hubbell Springs, Sandia, and Tijeras faults (Figure 4-4). For more detailed information, refer to SNLA (1993b and 1993a).

Soils. Well-drained loamy soils dominate throughout the Albuquerque Basin, with minor amounts of gravelly and stony soils along arroyos and on mountains (SNLA 1993a). Description of the soil associations in Bernalillo County and parts of Sandoval and Valencia counties, New Mexico, can be found in USDA-SCS (1977).

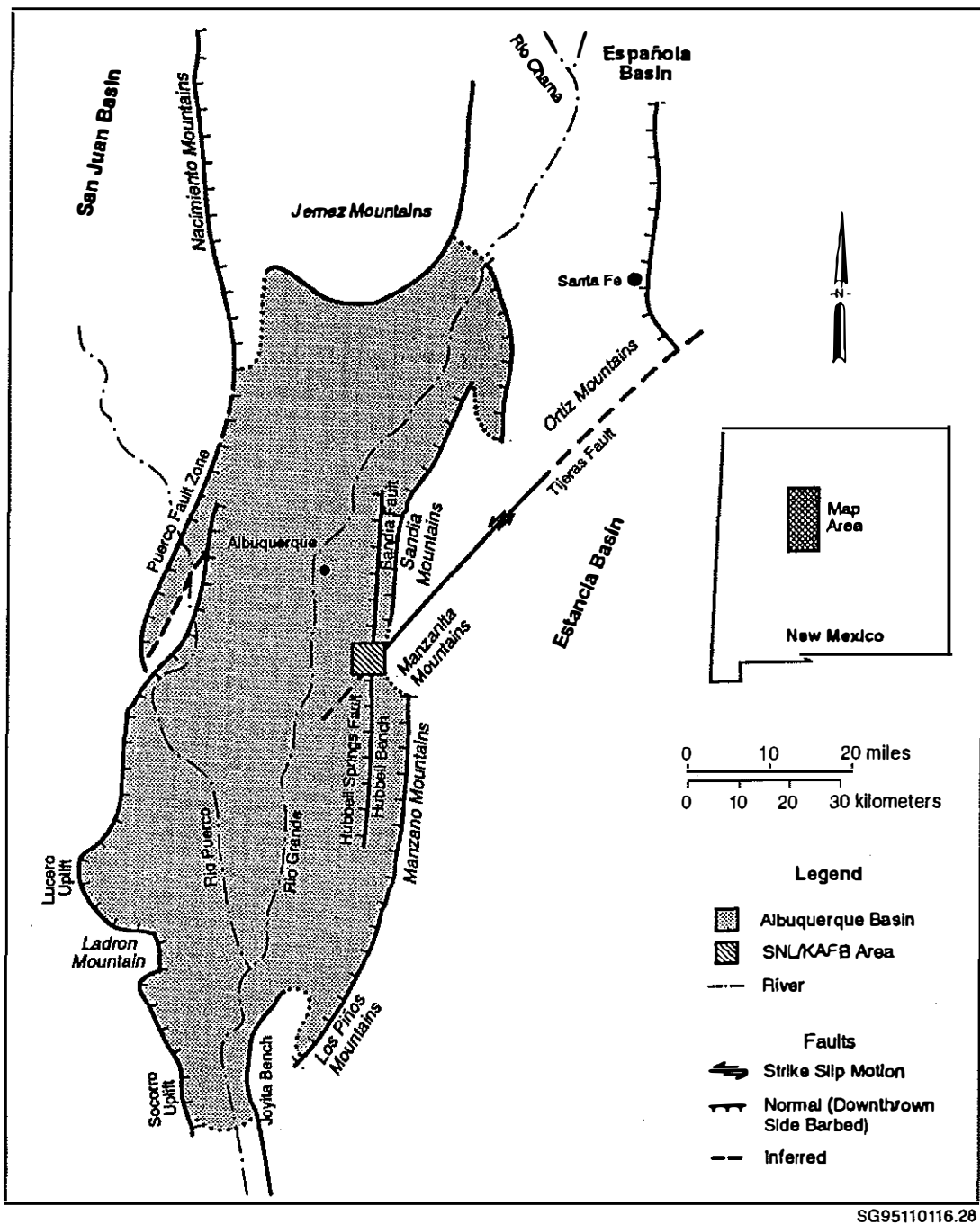
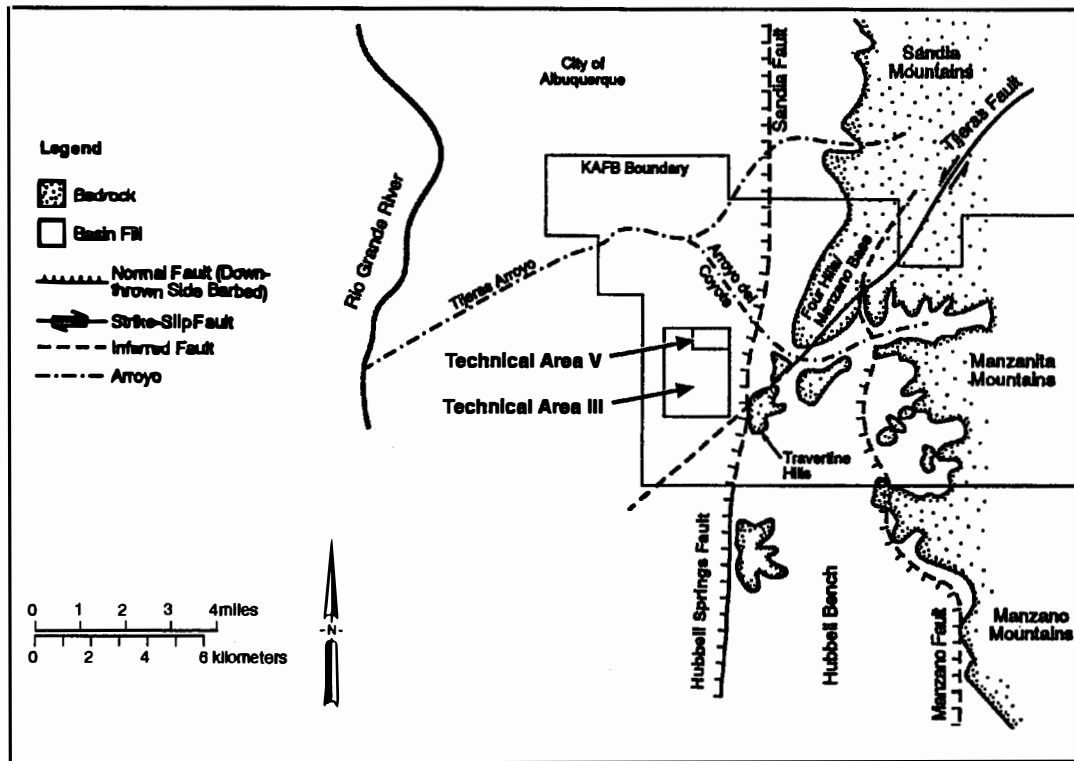


Figure 4-3. Location of the Albuquerque-Belen Basin (SNLA 1993a)



SG95110116.12

Figure 4-4. Fault Zones Near Sandia National Laboratories/New Mexico (SNLA 1993b)

4.1.6.2 Mineral Resources

Sand and gravel deposits are ubiquitous to the Albuquerque-Belen Basin. The known resources exposed on the SNL/KAFB are limited to industrial minerals, primarily quarry sands and gravels.

4.1.6.3 Site Stability

- | SNL/KAFB lies in the Uniform Building Code 2B seismic hazard area (DOE 1995b). This classification implies frequent moderate damage that corresponds to a Richter scale magnitude of 5 to 6.
- | Horizontal accelerations that are typical of these magnitudes range from 0.07 to 0.3 g. Seismically, the Albuquerque area is characterized as a region of high activity but relatively low magnitude and intensity and has been relatively stable for a long period of time. For more information on seismicity, refer to DOE (1993a), Massey and Coats (1995).

4.1.7 Air Quality

The climate and meteorology of the site are typical of a high desert plateau (Culp et al. 1993). A brief characterization of the climate is presented in Appendix D.

4.1.7.1 Nonradiological Air Quality

The SNL/NM is located within the Albuquerque-Mid Rio Grande New Mexico Intrastate Air Quality Control Region (DOE 1993b). Ambient air quality is regulated by the Albuquerque/Bernalillo County Air Quality Control Board (SNLA 1993b), which also monitors compliance with federal and state air quality regulations. Air quality in the city of Albuquerque is generally good.

During many winter nights (those characterized by clear skies and light winds), a low-level atmospheric inversion can form, trapping pollutants near the surface in the metropolitan area. This inversion can create periods of poor air quality. Pollutant emissions of carbon monoxide (CO) and particulate matter (PM₁₀) can be a concern under these conditions.

Primary sources of these pollutants are mobile vehicle exhaust and woodburning (DOE 1993a). Carbon monoxide levels have exceeded U.S. Environmental Protection Agency ambient air quality standards (40 CFR 81.332) on occasion. Visibility degradation can also be a problem in the region (SNLA 1987).

Air quality under ambient conditions at SNL/NM is shown in Table 4-2. This table compares SNL/NM maximum ambient background concentrations in air with the most stringent Ambient Air Quality Standards. Data on maximum background concentrations are from air quality monitoring in the vicinity of SNL/NM during 1991 and 1994. With the exception of ozone, baseline air quality concentrations at SNL/NM do not exceed any applicable guidelines or regulations. Principal sources of criteria air pollutants at SNL/NM are the steam plant, paint shops, toxic machine shop, process development laboratory, and the emergency diesel generator plant at Technical Area I. Explosives testing at Technical Area II is also a significant source (DOE 1993a). Other emissions include fugitive particulate emissions from waste-burial activities, other process emissions, vehicular emissions, and temporary emissions from various construction activities.

4.1.7.2 Radiological Air Quality

Calculations indicate that small quantities of hydrogen, nitrogen, oxygen, argon, krypton, and xenon were released to the atmosphere as a result of SNL/NM 1993 operations. Eight facilities at SNL/NM reported releases of airborne radionuclides during 1993 (Culp et al. 1994). A total of 3.2 Ci of argon, 0.62 Ci of nitrogen, 0.012 Ci of oxygen, and 1.9 Ci of hydrogen were released as a result of SNL/NM activities in 1993. The radioactive air emissions at SNL/NM were so small, they were not measurable with the existing monitors at those facilities. Therefore, the radionuclide release data are calculated based on

Table 4-2. Comparison of Air Quality Standards and Maximum Concentrations at Sandia National Laboratories

Pollutant	Averaging Time	Most Stringent Regulation or Guideline ($\mu\text{g}/\text{m}^3$)	Maximum Background Concentration ($\mu\text{g}/\text{m}^3$) ^(a)
Carbon Monoxide (CO)	8-h 1-h	10,000 ^(b) 15,000 ^(b)	7600 ^(c) 13,700
Hydrogen Sulfide (H ₂ S)	1-h	14 ^(b)	(d)
Lead (Pb)	Calendar qtr. 30-Day	1.5 ^(f) 3.0 ⁽ⁱ⁾	(d) 0.084 ⁽ⁱ⁾
Nitrogen Dioxide (NO ₂)	Annual 24-h	94 ^(b) 188 ^(b)	(g) 77 ⁽ⁱ⁾
Ozone (O ₃)	1-h	118 ^(b)	192 ^(c) /96 ⁽ⁱ⁾
Particulate Matter (PM ₁₀) ^(h)	Annual 24-h	50 ^(f) 150 ^(f)	36 ^(c) 104 ^(c) /66 ⁽ⁱ⁾
Sulfur Dioxide (SO ₂)	Annual 24-h 3-h	52 ^(b) 262 ^(b) 1300 ^(f)	4 ⁽ⁱ⁾ 16 ⁽ⁱ⁾ 22 ⁽ⁱ⁾
Total Reduced Sulfur	1-h	4 ^(b)	(d)
Total Suspended Particulates	Annual 30-d 7-d 24-h	60 ^(b) 90 ^(b) 110 ^(b) 150 ^(b)	(d) (d) (d) (d)
Hazardous Air Pollutants and Other Toxic Compounds:			
1,1,1-Trichloroethane	8-h	1	(d)
Acetone	8-h	5900 ^(b)	(d)
Amyl Acetate	8-h	5300 ^(b)	(d)
Hydrogen Chloride	8-h	70 ^(b)	(d)
Isopropyl Acetate	8-h	9500 ^(b)	(d)
Isopropyl Alcohol	8-h	9800 ^(b)	(d)
Methyl Alcohol	8-h	2600 ^(b)	(d)
Methylene Chloride	8-h	2610 ^(b)	(d)
Toluene	8-h	3750 ^(b)	(d)
Trichloroethylene	8-h	250 ^(b)	(d)
Trichlorotrifluoroethane	8-h	1	(d)
Xylene	8-h	4350 ^(b)	(d)
(a) Maximum of the concentrations as provided from the ambient air quality network (b) State standard (20 NMAC) (c) Ambient air quality monitoring data for 1991 (d) Data unavailable (e) Not estimated because potential release is negligible (f) Federal standard (40 CFR 50) (g) Data not representative (h) Particulate matter less than 10 microns in diameter (i) Ambient air quality monitoring for 1994 from the SNL/NM Clean Air Network (j) City of Albuquerque/Bernalillo County Ambient Air Quality Standard (20 NMAC 11.01) December 1, 1995			

theoretical parameters, such as reactor operating power and the generation rates per unit power for activation products and noble gases (such as argon) from the reactors in Technical Area V.

4.1.8 Water Quality

This section summarizes the surface water and groundwater resources at SNL/NM. Additional information is available in SNLA (1993b and 1993a).

4.1.8.1 Surface Water

The major surface water feature of the Albuquerque area is the Rio Grande, which flows southward with an annual average flow of $9.0 \times 10^9 \text{ m}^3$ (730,000 acre-feet) (SNLA 1993c). The Rio Grande is located approximately 11 km (7 mi) west of SNL/KAFB. The major surface drainage feature is the Tijeras Arroyo, which flows westward from the Sandia and Manzano mountains to the Rio Grande. Arroyo del Coyote, Tijeras Arroyo, and all other surface water features at SNL/KAFB are ephemeral streams, with the exception of small portions of Arroyo del Coyote, near Coyote Springs, and G Spring, which are intermittent.

Floods in the Albuquerque area usually occur between May and October during high-intensity thunderstorms (SNLA 1993c). During heavy precipitation, the arroyos effectively collect runoff from the mountains and divert surface flow away from the area. Floods in Tijeras Arroyo and Arroyo del Coyote are characterized by high peak flows, small volumes, and short durations. The heaviest precipitation to date in this area has not produced general flooding in Technical Area V, which is the location of the Annular Core Research Reactor.

4.1.8.2 Groundwater

The hydrogeology within the vicinity of the Annular Core Research Reactor east of the faults is poorly understood because there are few wells, and the geology between the faults and the canyons of the Manzanita Mountains is complex (DOE 1988). The valley floor consists of unconsolidated and semi-consolidated sands, gravels, silts, and clays of the Santa Fe Formation (SNLA 1993c).

4.1.9 Ecological Resources

The Annular Core Research Reactor is located in a highly developed area. Consequently, few natural ecological features in the immediate area would be affected by the proposed activities; therefore, only a brief discussion of ecological resources is provided.

4.1.9.1 Terrestrial Resources

The semidesert southwest climate combines with the low water availability to produce many species of drought resistant plants, such as cacti and other xerophytes. The mesa vegetation on KAFB consists

mostly of grasses and shrubs and is typical of that found in similar habitats in central New Mexico. The size and diversity of wildlife populations is thought to be limited by the poor availability of water (DOE 1993a). Higher elevations contain juniper (*Juniperus spp.*) trees and cacti. Disturbed areas are often invaded by Russian thistle (*Salsola kali*) (Culp et al. 1992).

4.1.9.2 Aquatic Resources

Naturally occurring permanent surface water bodies are found in several locations in KAFB, but outside of SNL/NM Technical Areas. The most significant springs include Coyote Springs, Sol se Mete Spring, and G Spring (DOE 1995h). The largest of these is only a few acres in extent (Fischer 1990). Some artificial ponds are also found within KAFB. Lake Christian is an 0.8-hectare (2-acre) permanent pond adjacent to a KAFB testing facility 1.6 km (1 mi) northeast of the Inhalation Toxicology Research Institute (DOE 1995h). Permanent ponds are also found on the golf course, 1.6 km (1 mi) southeast of Technical Area IV.

4.1.9.3 Wetlands

A wetland inventory of SNL/NM has been conducted by KAFB. Coyote Springs, Sol se mete Spring, and G Spring provide the most significant areas of natural wetlands within KAFB (Fischer 1990). Coyote Springs supports a number of cottonwoods and saltcedars, cattails, rushes, and wetland grasses. The other springs are located in canyons above Coyote Springs. These have been partially developed and are not associated with significant wetland habitat, although they do provide a water source for local wildlife.

Some artificial ponds also provide wetland-like habitats. These ponds may be used by migratory waterfowl in the spring and fall.

4.1.9.4 Threatened and Endangered Species

No federally listed threatened or endangered species are known to occur on SNL/NM (DOE 1993a; Fischer 1990). Grama grass cactus (*Pediocactus papyracanthus*), a federal candidate and state-listed endangered species, has been reported in grasslands on KAFB. The peregrine falcon (*Falco peregrinus*) and the spotted bat (*Euderma maculatum*), both federal candidate and state-listed endangered species, could potentially occur in the mountainous areas of KAFB surrounding SNL/NM, but the likelihood is low because of the poor quality habitat for these species.

4.1.10 Noise

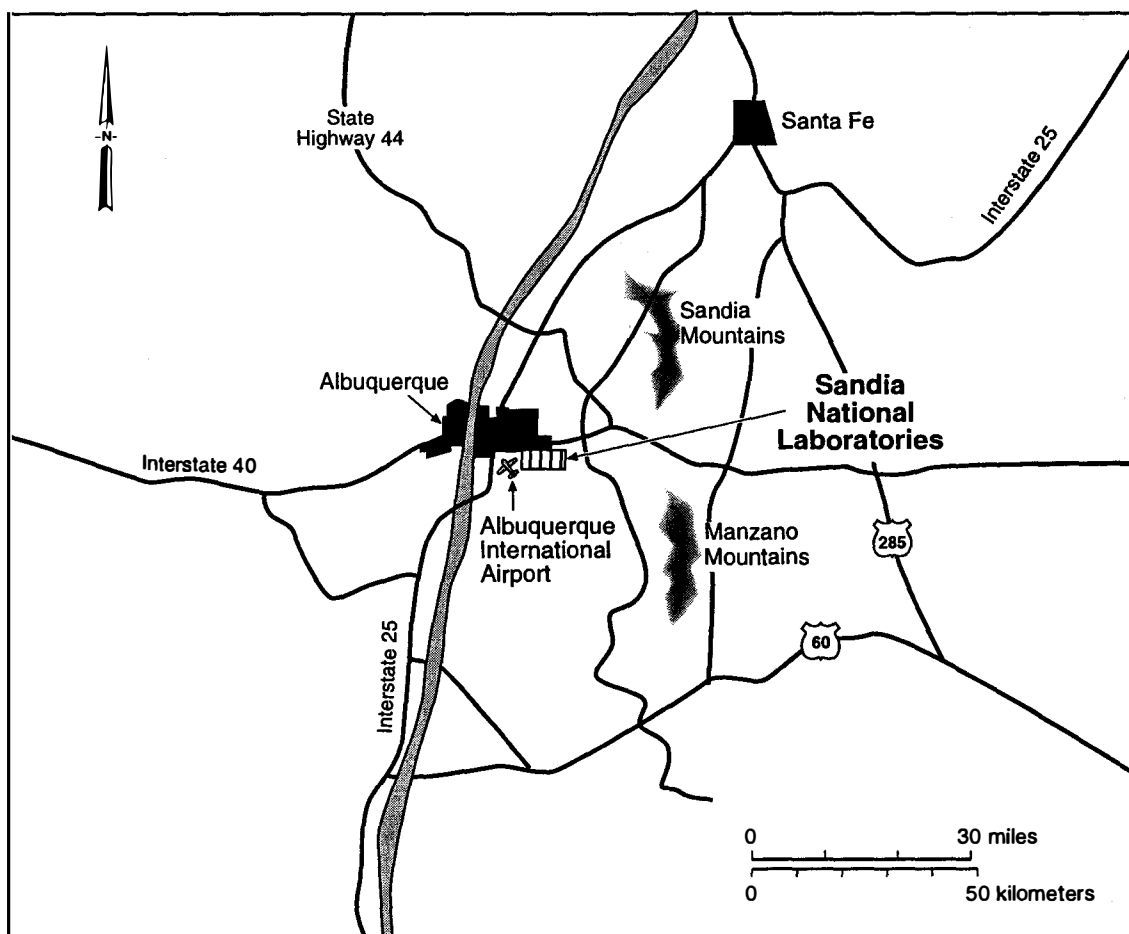
The potential for noise to result in community complaints depends on terrain, vegetation, and existing noise levels. In undeveloped areas, noise levels may range from 30 to 40 dB(A). At industrial locations, background noise levels range from 50 to 70 dB(A) and are largely influenced by traffic. Community noise regulations apply at the site or facility boundary. Background noise levels for the Annular Core Research Reactor are dominated by traffic and industrial activities.

4.1.11 Transportation

This section describes the regional and local transportation infrastructure affected by the alternatives involving SNL/NM. Included are descriptions of the highway and air transportation infrastructure that would be used to support production of Mo-99 at SNL/NM. No rail shipments are planned at SNL/NM to support production of Mo-99.

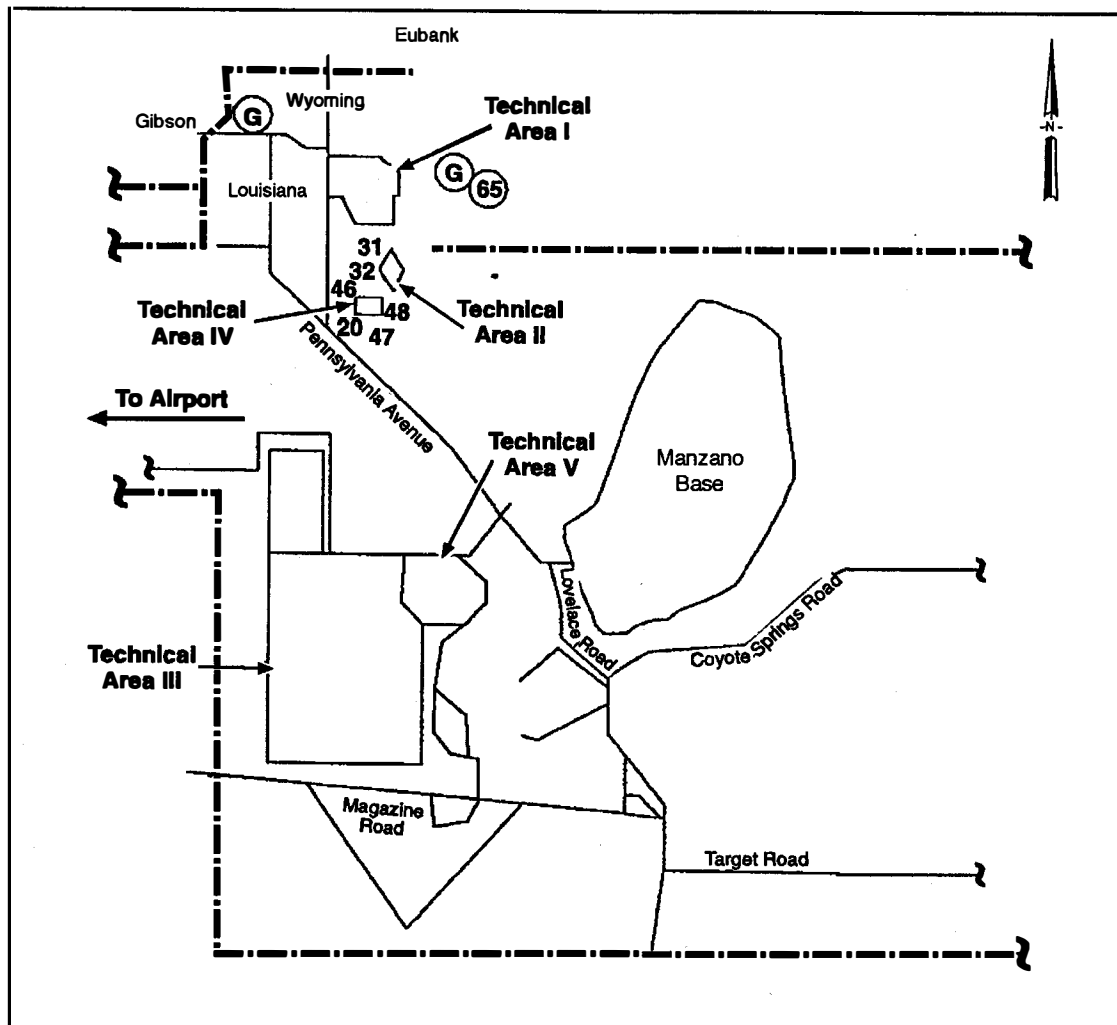
4.1.11.1 Roadways

Regional and local transportation routes are shown in Figures 4-5 and 4-6. Interstate 40 runs approximately east-west through Albuquerque and is approximately 1.6 km (1 mi) north of the SNL/NM site boundary at its nearest approach. Interstate 25 runs approximately north-south and is approximately 2.6 km (1.6 mi) west of the SNL/NM site boundary at its nearest approach. Other significant regional highways include U.S. 60, approximately 40 km (25 mi) south of SNL/NM, and U.S. 285, approximately 44 km (28 mi) east of the site.



SG95110116.11

Figure 4-5. Major Transportation Services Near Sandia National Laboratories/New Mexico



SG95110116.9

Figure 4-6. Local Transportation Routes Near Sandia National Laboratories/New Mexico

4.1.11.2 Airports and Air Traffic

The Albuquerque International Airport shares runways and other flight facilities with KAFB, forming an integral unit, and consists of all the private and commercial facilities located at the westernmost part of the airfield complex. The airport terminal and maintenance facilities are located 9.3 km (5.8 mi) northwest of the Technical Area V complex, where the activities associated with the proposed action would occur. This area is controlled by civil authorities, and the SNL/NM Emergency Plan provides for proper and timely cooperation with those authorities.

Final isotopic products would be transported by truck from SNL/NM to the airport's air freight area located south of the passenger terminal, across the main east-west runway. Product casks would be transported on KAFB using the Air Force access road south of the main east-west runway. No runways would be crossed because access and perimeter roads would be adequate. The Albuquerque International Airport has a limited number of direct flights (passenger or cargo) to Boston, Chicago, and St. Louis where the medical isotope distributors are located; therefore, shipments would be transported to distribution air freight hubs connecting with each of these cities. Figure 4-5 shows the location of Albuquerque International Airport with respect to the SNL/NM and interconnecting roadways. Air traffic data were not available for the airport and the distribution hubs.

4.1.12 Radiological Public Health and Safety

This section describes radiological exposures to members of the community and to workers at SNL/NM.

4.1.12.1 Current Radiological Environment

An Environmental Radiological Monitoring Program has been maintained at SNL/NM since 1959. The program staff collect soil, arroyo sediment, vegetation, and water samples that are analyzed according to established plans and procedures. In addition to these sampling and monitoring activities, another program that began in 1981 uses thermoluminescent dosimeters to measure ambient levels of external gamma radiation at each major facility. The thermoluminescent dosimeter monitoring locations are also present around the SNL/NM perimeter and at locations in the surrounding community.

The National Emission Standards for Hazardous Air Pollutants (NESHAP) maximally exposed individual was determined to be located at the KAFB Underground Munitions Storage Center facility on KAFB. As shown in Table 4-3, the maximum effective dose equivalent calculated for this location was 0.0016 mrem per year (mrem/yr), or 2% of the 0.1 mrem/yr dose that would require continuous monitoring

Table 4-3. Estimated Public Radiation Exposure from SNL/NM Activities
(population within 80 km [50 mi] of SNL/NM)

	1991	1992	1993
*MEI effective dose equivalent	0.0014 mrem	0.0034 mrem	0.0011 mrem
% of 10 mrem/yr dose limit	0.01%	0.03%	0.02%
Total population collective dose from operations	0.018 person-rem	0.020 person-rem	0.027 person-rem
Total population collective dose from natural background	180,000 person-rem	180,000 person-rem	180,000 person-rem
* MEI - Maximally exposed individual			

by NESHAP. The total population dose within the 80-km (50-mi) radius surrounding SNL/NM was calculated to be 0.027 person-rem during 1993 from SNL/NM operations, compared with 57,000 person-rem from external exposure to natural background radiation and 180,000 person-rem from all natural sources including radon. The 1990 U.S. Census figures indicate that 385,000 people live within the city limits, and more than 480,000 live in the metropolitan statistical area.

Argon is produced and released from operations of the Annular Core Research Reactor. The maximum reactor power for the Annular Core Research Reactor is estimated at 1.06×10^7 MJ/yr. Power production at that rate would release 218 Ci/yr of argon (LATA 1991). Although the Annular Core Research Reactor does not currently operate at maximum capacity, the dose calculated for maximum capacity is less than 0.1 mrem/yr to the maximally exposed individual at the Kirtland Underground Munitions Storage Complex (closest to the source).

Current emissions from the Hot Cell Facility result from disassembling nuclear components. Only gases are released on a routine basis. A potential release is based on a release fraction of 1×10^{-6} for bulk solids, 1×10^{-3} for particulate, and 1.0 for gaseous materials. For the Hot Cell Facility, it is assumed that all of the fuel material is solid except for gaseous iodine, tritium, and krypton. For maximum capacity, the calculated dose for the maximally exposed individual at the Kirtland Underground Munitions Storage Complex, located 0.62 km (1 mi) northwest of Technical Area V, is 2.1×10^{-3} mrem/yr (LATA 1991).

4.1.12.2 Present Radiological Exposures of Workers in Technical Area V

Table 4-4 shows the radiological doses received by personnel working in the Annular Core Research Reactor/Hot Cell Facility area during 1993 and 1994. For comparison, the annual allowable dosages for a radiological worker are set by DOE at 5 rem and 50 rem for full body and extremity dosages, respectively. The SNL/NM has set an administratively controlled limit of 500 mrem/y for a radiation worker.

1 **Table 4-4.** Radiation Doses Received by Personnel Working at the Annular Core Research Reactor/Hot Cell Facility Area During 1993 and 1994 (data from Monthly Exchange Dosimetry Reports, Radiological Protection Department, Dept. 6521, SNL/NM)

1994 Dose (9 months)	Rem			1993 Dose (12 months)	Rem		
13 Workers	Whole Body	Skin	Extremity	12 workers	Whole Body	Skin	Extremity
Minimum	0.010	0.010	0.010	Minimum	0.034	0.034	0.096
Maximum	0.519	0.748	1.695	Maximum	0.418	0.677	1.465
Average	0.177	0.231	0.351	Average	0.112	0.182	0.474
4 workers with no dose				1 worker with no dose			

4.1.13 Site Services

Electricity is supplied to SNL/NM and much of southeast Albuquerque through the Public Service Company of the New Mexico switching station on Eubank Boulevard in Albuquerque. Voltage is stepped down through transformers to two subtransmission voltages, 46 kV and 115 kV, for distribution through five subtransmission feeders.

KAFB is responsible for the overall natural gas system for the base. The distribution system is owned by DOE and operated by SNL/NM. Natural gas is purchased from KAFB, which buys it commercially. Fuel oil is stored for refueling remote-site tanks and for emergency supply to the steam plant. The steam plant supplies steam for space heating, hot water converters, absorption chillers, and processes.

The SNL/NM is responsible for the water collection system at its technical areas and in the Coyote Test Field; KAFB is responsible for the system base-wide. The existing resource requirements are summarized in Tables 4-5 and 4-6.

Table 4-5. Existing SNL/NM Utility Resource Requirements

Utility Resources	Average Daily Consumption	Peak Demand	System Capacity
Electricity	548 MWh	34 MW	50 MW
Natural Gas	1,500,000 ft ³	250,000 ft ³ /hr	250,000 ft ³ /hr
Water (at SNL/NM)	1,000,000 gal	1400 gpm	2800 gpm
Water (in Technical Area V)	2,500 gal	N/A	N/A
Conversions: To convert gallons (gal) to liters (L), multiply by 3.785. To convert cubic feet (ft ³) to cubic meters (m ³), multiply by 0.028317.			

Table 4-6. Existing SNL/NM Chemical Resource Requirements

Chemical Resources	Total Annual Consumption	Storage Capacity
Nitrogen	720,000 gal	72,000 gal
Argon	400,000 gal	46,000 gal
Hydrogen	1,152,000 ft ³	76,000 ft ³
Oxygen	5,330,000 ft ³	533,000 ft ³
Conversions: To convert gallons (gal) to liters (L), multiply by 3.785. To convert cubic feet (ft ³) to cubic meters (m ³), multiply by 0.028317.		

4.1.14 Waste and Spent Nuclear Fuel Management

Each waste management portion of Section 4.0 summarizes the various wastes generated and stored at each of the sites considered in this environmental impact statement. Volume production rates, as well as storage or disposal methods, are addressed. The goal is to provide a general overview of current site conditions, thus providing a foundation upon which impacts can be determined. Categories discussed are spent nuclear fuel, low-level waste, and low-level mixed waste. Waste volume production rates for medical isotope production and the impacts associated with each alternative are addressed in Section 5.14.

4.1.14.1 Introduction

Radioactive waste at SNL/NM is generated in both technical and remote test areas from research, development, and technology activities. Most of the waste consists of contaminated equipment, combustible decontamination materials, and cleanup debris. SNL/NM does not currently generate high-level waste. Radioactive waste is managed by the SNL/NM Radioactive Waste Management Program.

4.1.14.2 Spent Nuclear Fuel

Facilities at SNL/NM currently store and generate relatively small quantities of spent nuclear fuel. These facilities include the Manzano Storage Structures, the Annular Core Research Reactor, the Sandia Pulse Reactor II and III and Critical Assembly, Hot Cell Facility and the Special Nuclear Materials Storage Facility. The SNL/NM reactors operate as needed on a low duty cycle, so the fission product inventories remain low and the fuel loading lasts for the life of the reactor, thus eliminating routine generation of spent nuclear fuel. The quantity of spent nuclear fuel at SNL/NM in 1995 was estimated at 440 kg (heavy metal). Except for a few broken plates that are in storage, the fuel at SNL/NM is still in use in the reactors (DOE 1995g).

4.1.14.3 Low-Level Radioactive Waste

All low-level wastes and mixed wastes at SNL/NM are temporarily stored in DOE-approved containers above ground. All low-level waste packages will be transported by commercial carriers to the Nevada Test Site for disposal. In 1991, SNL/NM generated approximately 15,746 L (4160 gal) of liquid low-level waste and 10 m³ (13 yd³) of solid low-level waste (DOE 1993a). SNL/NM currently generates approximately 70.8 m³ (2500 ft³) of uncompacted low-level waste each year (Massey and Coats 1995).

4.1.14.4 Low-Level Mixed Waste

Low-level mixed wastes at SNL/NM include radioactively contaminated oils and solvents, radioactively contaminated or activated lead, or other heavy metals. Other mixed wastes may be generated as a result of defense research testing. Completion of the Radioactive and Mixed Waste Management Facility is expected in 1996. This facility will provide a centralized packaging and storage facility for low-level waste and mixed waste. In 1991, SNL/NM generated approximately 1820 L (480 gal) of liquid mixed

- | waste and 3 m³ (4 yd³) of solid mixed waste (DOE 1993a). The SNL/NM has an approximate cumulative volume of 66.1 m³ (86 yd³) of low-level mixed waste that is made up mostly of radioactive asbestos (DOE 1994b).

4.2 Los Alamos Environment

4.2.1 Overview

Los Alamos National Laboratory (LANL) is located in north-central New Mexico, 97 km (60 mi) north-northeast of Albuquerque, 40 km (25 mi) northwest of Santa Fe, and 32 km (20 mi) southwest of Española in Los Alamos and Santa Fe counties.

Land use in the general region consists of several small communities including Los Alamos and several recreation areas. The surrounding land is largely undeveloped with large tracts of public land north, west, and south of LANL. Nearby recreational areas include Bandelier National Monument and Santa Fe National Forest.

Major public roads used at LANL include state roads 4, 501, 502, and Pajarito Road. The highway route from Albuquerque consists of Interstate 25 to Santa Fe, U.S. Highway 84 from Santa Fe to Pojoaque, and New Mexico State Highway 4 from Pojoaque to Los Alamos. New Mexico state highways 14 and 44 are also significant roadways in the region surrounding LANL.

Technical Area 2 (TA-2), the location of the Omega West Reactor, is located just south of the town of Los Alamos in the bottom of Los Alamos Canyon between two mesas. The north mesa is the location of the Los Alamos townsite, and the south mesa is the location of the main LANL technical area. The bottom of the canyon is wooded and relatively flat. A small ephemeral stream that runs through the bottom of the canyon is normally dry except for short periods during spring snowmelt runoff and after summer thunderstorms. Flash floods from heavy thunderstorms are possible at Los Alamos, especially affecting arroyos, canyons, and low spots.

Approximately 60% of LANL lands have been inventoried for archaeological and historical cultural resources, and over 1 500 sites have been recorded. None of these archaeological sites exists in or adjacent to the Omega West Reactor facility. The reactor itself has not been fully evaluated and recorded as a historical structure. The significance of the facility for inclusion in the National Register of Historic Places has not been completed.

Three fault zones are located in the LANL area: the Pajarito, Rendija Canyon, and Guaje Mountain faults. Although all three faults are geologically young, recent investigations of the faults suggest they are capable of producing future earthquakes. Seismic ground motion and shaking could affect the site stability at LANL through the erosional retreat of the cliffs forming mesa rims. During the past 500,000 years, several faults in the Los Alamos area are suspected of having produced seismic events with a magnitude of

6.5 to 7.8 on the Richter scale. Some evidence suggests that a single earthquake with a magnitude close to 5.5 has occurred in the Los Alamos area during the past 150 years.

Air samples are routinely collected from within the laboratory boundary, from nearby residential and community areas, and from the surrounding areas up to 80 km (50 mi) from the laboratory. Tritium and uranium-235 concentrations in 1992 were highest onsite, decreased slightly at the site perimeter, and were lowest at regional locations. Plutonium-238 was not detected away from the site perimeter; while plutonium-239,240 was detected only once out of 12 regional samples, and the maximum concentration was measured onsite. Americium-241 was seen in 40% of the regional samples, but its highest concentration was measured onsite.

The total cumulative mass of spent nuclear fuel (as of 1994) at LANL consists of approximately 86 elements. The total cumulative volume of retrievably stored transuranic waste (as of 1993) was 10,810.9 m³ (14,134 yd³) for contact handled and 91.3 m³ (119 yd³) for remote handled. Many areas throughout LANL generate liquid low-level waste. LANL has two onsite liquid low-level waste treatment facilities, a chemical treatment and ion-exchange plant, and a chemical treatment plant. As of 1993, the cumulative total of low-level waste onsite was 220,700 m³.

At LANL, 12 species that may occur that are listed as threatened or endangered by either the U.S. Fish and Wildlife Service or the New Mexico Department of Game and Fish. A total of 12 other species are considered candidates for inclusion on the federal endangered or threatened list or are considered rare by the state of New Mexico.

4.2.2 Land Use

Los Alamos National Laboratory is located in north-central New Mexico, 97 km (60 mi) north-northeast of Albuquerque, 40 km (25 mi) northwest of Santa Fe, and 32 km (20 mi) southwest of Española in Los Alamos and Santa Fe counties.

4.2.2.1 Los Alamos National Laboratory

Los Alamos National Laboratory occupies the southeastern portion of Los Alamos County (Figure 4-7). It is bordered by the Santa Fe National Forest to the north and west, the community of Los Alamos to the north, Bandelier National Monument to the east and south, the San Ildefonso Indian Reservation to the east, and the town of White Rock and the Rio Grande River to the southeast.

4.2.2.2 Technical Area-2

The developed acreage of LANL consists of 30 active technical areas (Figure 4-8). The Omega West Reactor (TA-2) is located in Los Alamos Canyon between two mesas just south of the town of Los Alamos. The reactor is in cold stand-down status with the tank drained and fuel removed. The north mesa is the location of the Los Alamos townsite, and the south mesa is the location of the main LANL technical

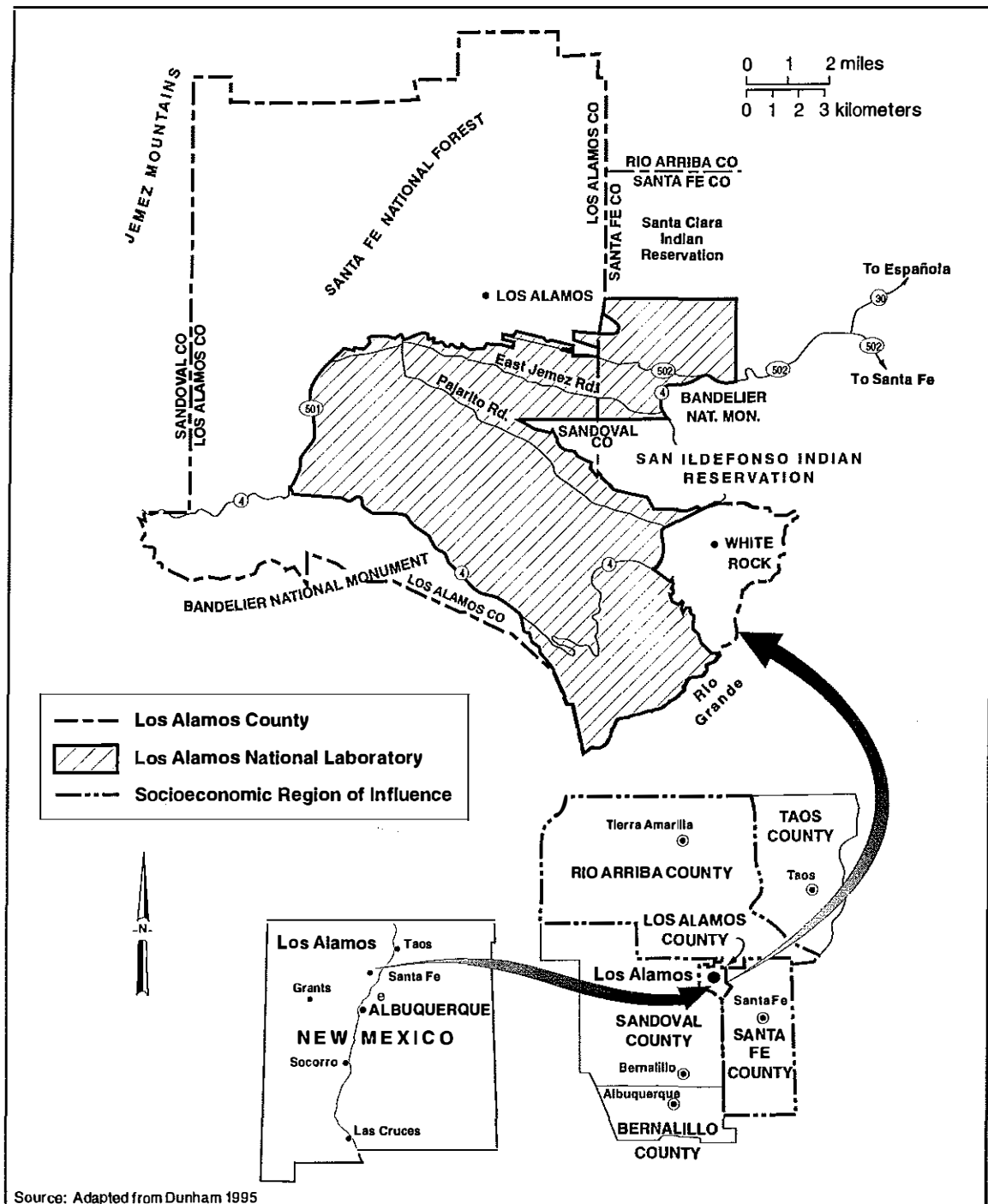
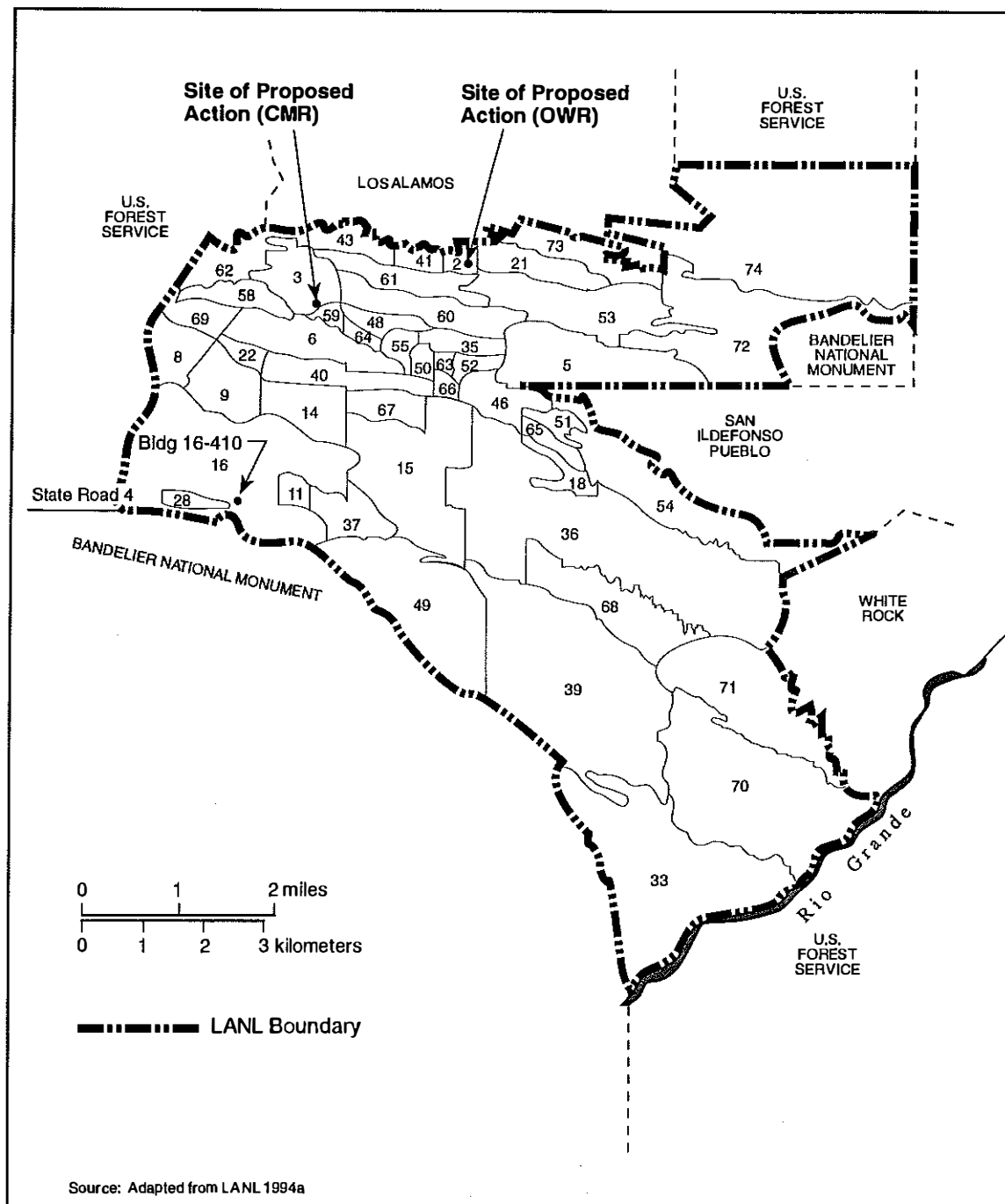


Figure 4-7. Regional Map of Los Alamos National Laboratory and Surrounding Area



SG95110116.3

Figure 4-8. Technical Areas of Los Alamos National Laboratory

area. East Jemez Road, the major entry to LANL, runs east-west, about 0.4 km (0.25 mi) south of TA-2, but TA-2 has relatively poor access and is quite isolated.

Los Alamos Canyon at TA-2 is approximately 410 m (1350 ft) wide at the top and 110 m (350 ft) deep. The canyon sides are very rough and rocky and are partially covered by pine trees, particularly on the south side. The bottom of the canyon is wooded and relatively flat for a width of about 60 m (200 ft). A small ephemeral stream that runs through the canyon is normally dry except for short periods during spring snowmelt runoff and after summer thunderstorms when runoff is sometimes transported beyond the site boundary.

Nearby land use includes trailer storage, a cable television facility, and a landfill. A private, mobile home park is located about 0.5 km (0.33 mi) southwest of the site.

4.2.2.3 Technical Area-3

Technical Area-3 (TA-3) of Los Alamos National Laboratory is essentially the *central business district* and is similar, in that respect, to a typical city with the usual sights and problems. These similarities include high density development, parking and traffic congestion, high land value, multi-story construction and redevelopment potential. The dominant land uses within this core area include: administrative and technical services; experimental science; physical support and infrastructure; theoretical and computational sciences; and special nuclear materials. The main part of the city of Los Alamos lies roughly north to northeast of TA-3, which is served by East James Road (501) that runs east-west, and by north-south trending Pajarito Road (See Figure 4.14). Designated as an industrial area, the majority of the elaborate facilities and personnel is located in TA-3, including the Chemistry and Metallurgy Research Facility where a portion of the Mo-99 process would take place. TA-3 is located south of South Mesa and north of Twomile Canyon toward the western end of Sigma Mesa.

The Chemistry and Metallurgy Research Facility is a 51,095 m² (550,000 ft²) reinforced-concrete building aligned in a north-south direction. The building contains a waste assay facility at the loading dock and a special nuclear material (SNM) vault. Wing 9 of this facility would be involved in the production of Mo-99 where target fabrication and post-irradiation hot cell operations to remove the Mo-99 would take place. Refer to Section 3.3.1.6 for more details on production activities.

4.2.3 Socioeconomic Environment

The LANL is located in north-central New Mexico in Los Alamos and Santa Fe counties, 97 km (60 mi) north-northeast of Albuquerque, and 40 km (25 mi) northwest of Santa Fe (Figure 4-7). The LANL Office of Community Relations estimates that 91.6% of the LANL employees reside in the tri-county region of Los Alamos, Santa Fe, and Rio Arriba counties (Massey and Coats 1995).

4.2.3.1 Demographic Characteristics

At the time of the 1990 census, the total population of the Los Alamos region of influence was 151,400. Of the population in the region of influence, 79% is white, with 50.1% having Hispanic background. Native Americans residing in Los Alamos, Rio Arriba, and Santa Fe counties account for 5% of the general population. Extending this region to include Sandoval County increases the percentage of Native Americans to just under 10% of the general population. Of 12 Native American populations near LANL, the closest are the Pueblos of San Ildefonso, Cochiti, Jemez, and Santa Clara.

Some 62.5% of the total population in the tri-county region is between the age of 18 and 65. Approximately 80.7% of this population has completed high school, and 30.5% has attained a baccalaureate degree or higher. A significant difference exists in educational attainment levels within the region.

The 1990 median and per capita income levels of the population in the tri-county region were \$30,408 and \$14,538. Approximately 15% of the tri-county residents fell below official poverty thresholds.

4.2.3.2 Economic Base

LANL is the largest employer in this tri-county region. For fiscal year 1993, the LANL payroll for the tri-county region was \$450 million for 7256 full-time personnel (Massey and Coats 1995). During the same year, LANL spent approximately \$220 million in procurement in the tri-county region (Massey and Coats 1995). Therefore, \$670 million (\$450 + \$220) in direct income was available for households and businesses to make additional purchases of products and services within or outside the tri-county region. A description of employment by economic sector within the tri-county region is provided in Table 4-7.

The average annual employment in the tri-county region during calendar year 1993 included 71,776 workers who earned a total of \$1.82 billion in wages (New Mexico State Department of Labor 1994). At the sector level, employment and wages were highest in the service, state or federal governments (including LANL), and gross trade sectors of the regional economy. Together these sectors accounted for 76% of the employment and 79% of the wages in the regional economy. The unemployment rate for the tri-county region as a whole was 5.5%. Employment and wages during 1993 were highest in Santa Fe County, followed by Los Alamos and Rio Arriba counties. The unemployment rate in Rio Arriba County during 1993 was nearly three times that of Santa Fe County and more than five times that of Los Alamos County.

In fiscal year 1993, LANL paid \$41 million in payroll taxes and \$6 million in additional tax payments within the tri-county region.

4.2.4 Cultural Resources

Approximately 60% of LANL lands have been inventoried for archaeological and historical cultural resources, and over 1500 sites have been recorded (LANL 1994a). None of these archaeological sites exists in or adjacent to either the Omega West Reactor Facility or the Chemistry and Metallurgy Research

Table 4-7. Regional Employment Profile (for 1993)

Economic Sectors	Santa Fe	Los Alamos	Rio Arriba	Totals
Agriculture	364	28	59	451
Construction and Mining	3,120	170	382	3,672
Manufacturing	2,016	63	315	2,394
Transportation and Utilities	1,056	66	268	1,390
Trade	12,725	1,236	1,480	15,441
F.I.R.E. ^(a)	2,311	341	216	2,868
Services	13,520	4,424	2,331	20,275
Government				
Federal	1,510	190	455	2,155
State	9,104	157	493	9,754
LANL	na	7,256	na	7,256
Local	3,613	1,081	1,426	6,120
Totals	49,339	15,012	7,425	71,776
Percent Unemployment	4.3%	1.3%	12.8%	5.5%
(a) F.I.R.E. is finance, insurance, and real estate.				
(b) na = not available				

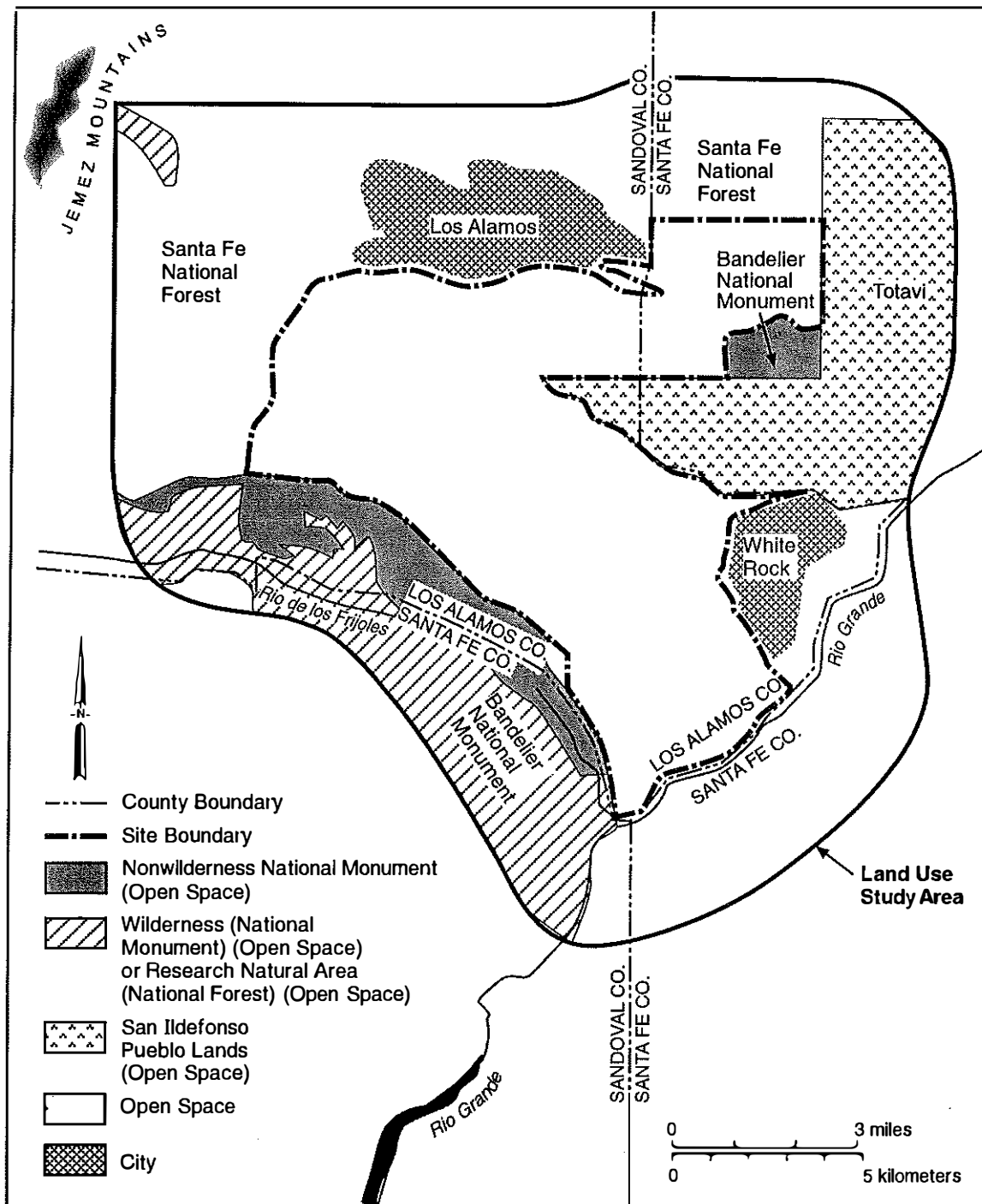
- | Facility in TA-3. The reactor has not been fully recorded and evaluated as a historical structure.
- | Preliminary studies to determine the Omega West Reactor's potential as a historic site have been initiated.

4.2.5 Aesthetic and Scenic Resources

- The topography of LANL affords spectacular views of the surrounding landscape of natural beauty, forested mountains, deep canyons, and the Rio Grande Valley. A number of recreational areas are nearby (Figure 4-9). Located immediately south of LANL, Bandelier National Monument is a popular public attraction. The Jemez Mountains rise above Los Alamos to the west and offer a vast array of scenic attractions. This mountainous terrain in the Santa Fe National Forest offers the public opportunities for fishing, hunting, skiing, hiking, swimming, camping, and horseback riding (LANL 1994b).

4.2.6 Geologic Resources

This section summarizes the physiography, geology, and seismic hazards at the Los Alamos National Laboratory. A more detailed summary of these subjects is found in DOE (1979).



SG95110116.10

Figure 4-9. Land Use for Los Alamos National Laboratory and Surrounding Area

4.2.6.1 General Geology

Physiography. LANL encompasses 111 km² (43 mi²) in north-central New Mexico and is located on narrow finger-like mesas, whose tops range in elevation from 2377 m (7800 ft) on the flanks of the Jemez Mountains to approximately 1890 m (6200 ft) at their eastern termination above the Rio Grande Valley. For more information on geology, refer to LANL (1992a).

Geology. The Pajarito Plateau forms a topographically high area along the western margin of the Rio Grande depression (DOE 1979). Sediments eroded from highland masses to the east and west to fill the depression and form the sedimentary rocks of the Miocene-Pleistocene aged Santa Fe Group (Figure 4-10). For more detailed information, refer to DOE (1979), LANL (1992a and 1993a).

The Omega West Reactor is located in Los Alamos Canyon, a deep narrow canyon that separates the laboratory to the south from the community of Los Alamos to the north. The upper part of the Otowi Member of the Bandelier Tuff is poorly exposed in Los Alamos Canyon due to extensive talus and colluvium cover (LANL 1993b). Discontinuous exposures of the Cerro Toledo interval may be observed in the lower slopes of Los Alamos Canyon. The primary unit exposed in the slopes and cliffs of Los Alamos Canyon is the Tshirege Member. Thick sections of the Tshirege are observable at several locations throughout the canyon and can be seen forming most of the spectacular cliffs throughout the Pajarito Plateau.

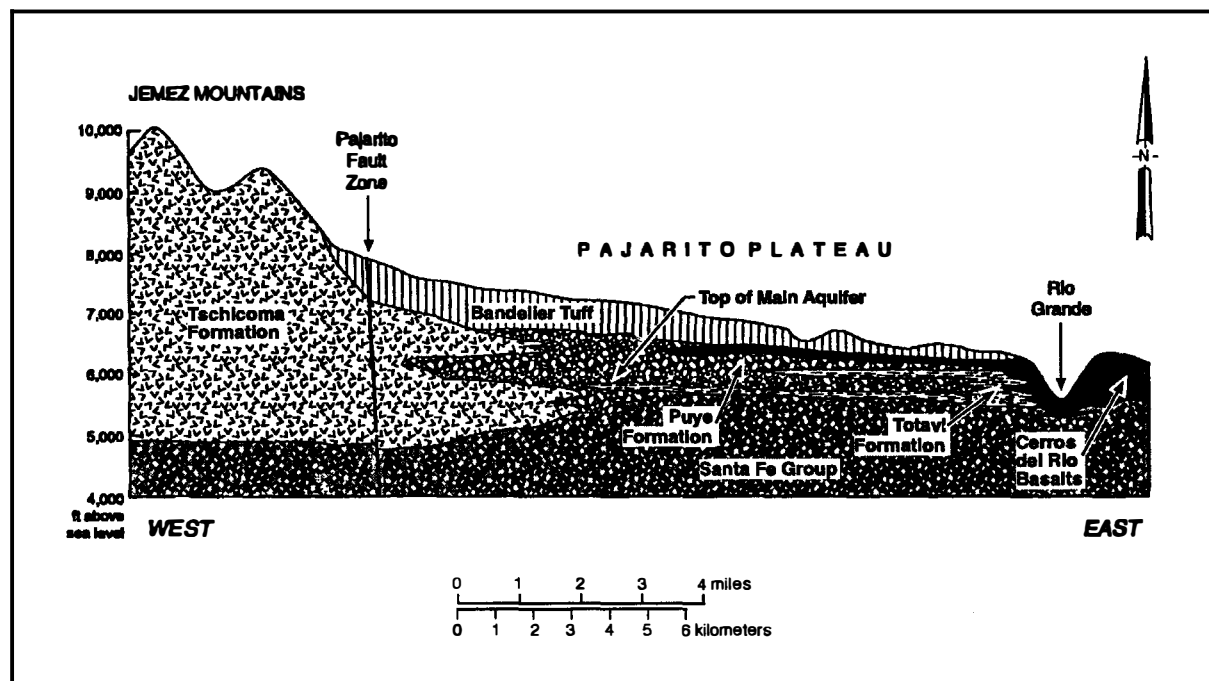
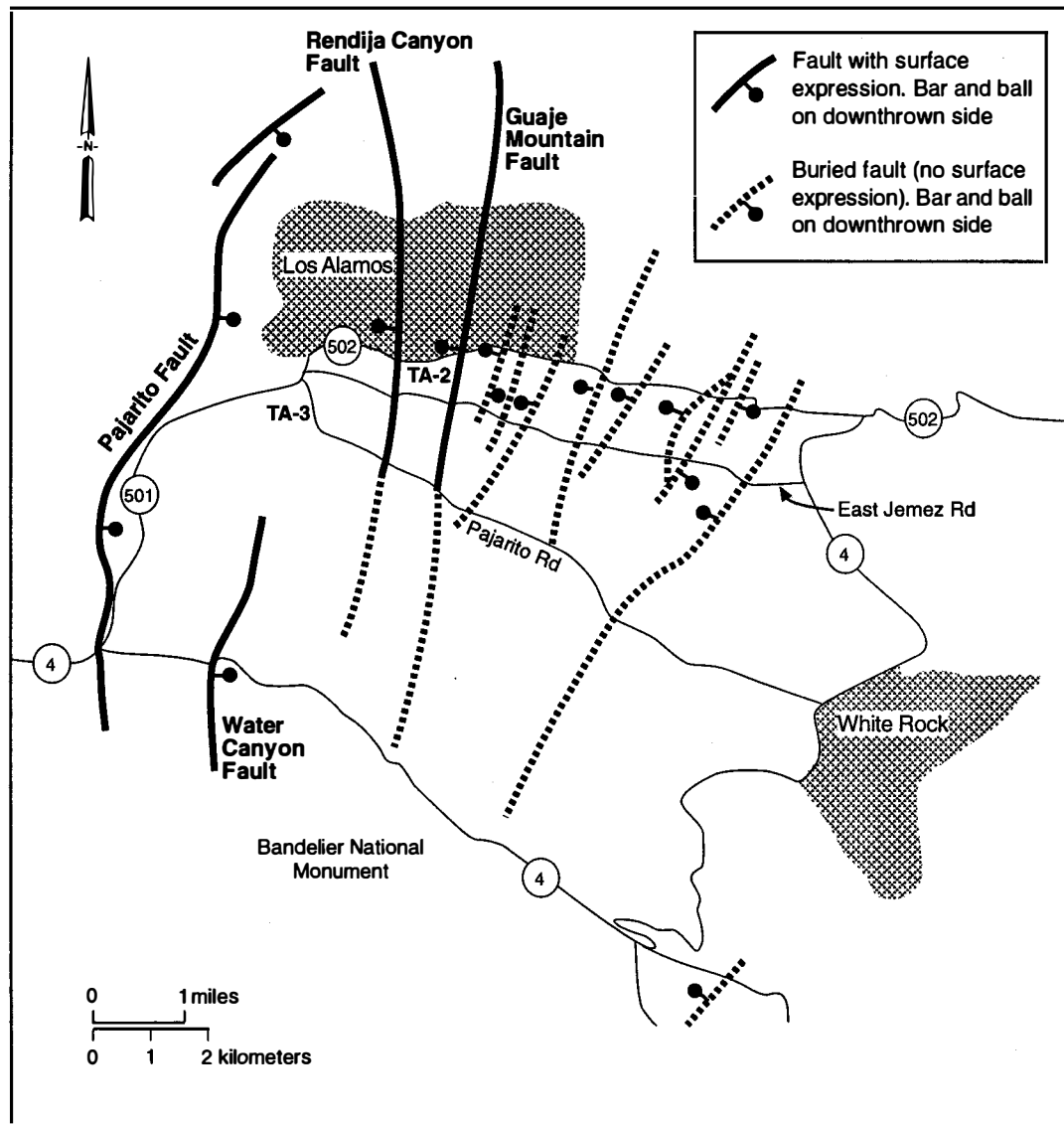


Figure 4-10. Stratigraphy of the Pajarito Plateau (LANL 1993d)

Structure. The geologic structure at LANL is dominated by three fault zones: the Pajarito, Rendija Canyon, and Guaje Mountain faults (Figure 4-11). The Pajarito fault is thought to mark the currently active western boundary of the Espanola Basin (Wong et al 1995). The Rendija Canyon and Guaje Mountain faults are shorter and secondary to the Pajarito fault. Recent investigations of the faults suggests that all three faults are geologically young and are capable of producing future earthquakes. The Guaje Mountain fault passes directly beneath TA-2 (LANL 1993a). The Rendija Canyon and Guaje Mountain faults are exposed just north of Los Alamos Canyon as zones of gouge and breccia up to several meters wide with visible stratigraphic offset. For more detailed information, refer to Wong et al. (1995) and LANL (1993a).



SG95110116.29

Figure 4-11. Fault Zones Surrounding Los Alamos National Laboratory

Soils. Soils mapped in TA-2 are generally poorly developed and are designated as Typic Ustorthents-rock outcrop complex soils (LANL 1993a). Soil covering TA-3 is primarily the Carjo Loam (LANL 1993c). Also present in TA-3 are the Tocal and Seaby series soils. A detailed description of these soil types can be found in Nyhan et al. (1978).

4.2.6.2 Mineral Resources

Sand, gravel, clay, pumice, and tuff resources are ubiquitous to Los Alamos County and the Pajarito Plateau (DOE 1979). None of these resources is considered unique to the Los Alamos site, and all are available in proximity to the DOE-controlled property.

4.2.6.3 Site Stability

Site stability at LANL could be affected by erosional retreat of cliffs and slopes forming mesa rims and by shaking during seismic ground motion (DOE 1995i). Erosional retreat of vertical cliffs in Los Alamos Canyon near the Omega West Reactor has produced at least 24 separate rockfall incidents from 1944 to 1993, with debris trapped in rock catchers ranging in size from approximately 140 to 9530 kg (300 to 21,000 lbs) (McLin 1993). Along the cliffs bordering the canyon, partially detached landslide blocks show that mass wasting may occur up to 23 m (75 ft) from the mesa edge (LANL 1993c). Single failures of this scale should be considered feasible along the rim of Los Alamos Canyon, particularly during seismic events. Erosional retreat estimates for the cliffs near the Omega West Reactor are on the order of 2 to 3 cm/1000 years (0.8-1.2 in./1000 years) (McLin 1993), suggesting that seismic shaking may be the critical triggering mechanism in major rock falls.

Studies suggest that several faults in the Los Alamos area have produced seismic events with a magnitude of 6.5 to 7.8 on the Richter scale in the past 500,000 years (DOE 1993a). Evidence exists for a single earthquake of Richter scale magnitude 5.5 occurring in the vicinity of Los Alamos over the past 150 years (Massey and Coats 1995). Los Alamos lies on the boundary between Zones 1 and 2 designated by the Uniform Building Code of 1991. LANL facility designs are based on the more restrictive Zone 2 criteria. In the event of an earthquake typical of Zone 2, the buildings would be expected to remain intact, and the distribution systems for water, gas, and other utilities would not be expected to rupture. Evaluating the earthquake risk at Los Alamos is based on the results of a study of seismic hazard for DOE sites (Coats and Murray 1984). The design basis earthquake has a ground surface acceleration of 0.30g and a predicted occurrence of once every 5000 years.

4.2.7 Air Quality

Los Alamos has a semiarid, temperate mountain climate. A brief characterization of the climate is presented in Appendix D.

4.2.7.1 Nonradiological Air Quality

Criteria pollutants, such as nitrogen dioxide (NO₂), carbon monoxide (CO), hydrocarbons, particulate matter, and sulfur dioxide (SO₂) are emitted by facility power plants, steam plants, asphalt plants, and local space heaters (Table 4-8). Toxic and other hazardous pollutants are emitted by some site industrial and laboratory activities (LANL 1994a).

The LANL operated or accessed a network of nonradiological ambient air monitoring devices (LANL 1994a) to routinely evaluate the background concentration of criteria pollutants, beryllium, acid precipitation, and visibility. The measured ambient concentration of all monitored pollutants met all applicable state and federal standards.

Beginning in fiscal year 1995, criteria pollutants were no longer monitored on a routine basis because past observed values were low relative to standards. Measurements are to be made on an as-needed basis for activities with potential for pollution (Jardine 1995).

Table 4-8. Nonradiological Ambient Air Monitoring Results in the Region of Los Alamos National Laboratory (for 1992)

Pollutant	Averaging Time	Unit	New Mexico Standard	Federal Standards		Measured Concentration
				Primary	Secondary	
Sulfur Dioxide ^(a)	Annual Arithmetic Mean	ppm	0.02	0.03		0.0005
	24 h	ppm	0.10	0.14		
	3 h	ppm			0.05	
	1 h	ppm				0.009
Total Suspended Particulate Matter	Annual Geometric Mean	µg/m ³	60			
	30 d	µg/m ³	90			
	7 d	µg/m ³	110			
	24 h ^(b)	µg/m ³	150 ^(b)			
PM ₁₀ ^(a)	Annual Arithmetic Mean	µg/m ³		50	50	8
	24 h	µg/m ³		150	150	21
Ozone ^(a)	1 h	ppm	0.06	0.12	0.12	0.076
Nitrogen Dioxide ^(a)	Annual Arithmetic Mean	ppm	0.05	0.053	0.053	0.002
	24 h	ppm	0.10			
	1 h	ppm				0.02
Lead	Calendar Quarter	µg/m ³		1.5	1.5	
Beryllium ^(c)	30 d	µg/m ³	10			0.02
Heavy Metals	30 d	µg/m ³	10			
(a) Measurements made at Bandelier Monitoring Compound. (b) Maximum concentration, not to exceed more than once per year. (c) Measurement made at Technical Area 52. Source: LANL 1994a						

4.2.7.2 Radiological Air Quality

Los Alamos National Laboratory supports an ongoing environmental surveillance program, as required by DOE Order 5484.1 (DOE 1981) and Order 5400.1. This program maintains routine monitoring for radiation, radioactive materials, and hazardous chemicals at the laboratory and in the surrounding region. Samples of air particulates, gases, waters, soils, sediments, and foodstuffs are collected for analysis from monitoring stations within the laboratory boundary, in nearby residential and community areas, and in surrounding areas up to 80 km (50 mi) from LANL. The samples are used to document compliance with appropriate standards set by DOE and the U.S. Environmental Protection Agency (EPA 1989a, 1989b). Radionuclide concentrations in air samples collected in 1992 from within the LANL boundary, from nearby residential and community areas, and from the surrounding areas up to 80 km (50 mi) from the laboratory are tabulated in Table 4-9.

In general, tritium concentrations were highest onsite, decreased slightly at the site perimeter, and were lowest at regional locations. Average concentrations of uranium-235 followed a similar pattern. The average uranium-238 concentration was highest at regional sampling locations, followed by waste sites, onsite, and perimeter locations, respectively. Plutonium-238 was not detected away from the site perimeter; while plutonium-239,240 was detected only once out of 12 regional samples, and the maximum concentration was measured onsite. Americium-241 was seen in two out of five of the regional air samples, and its highest concentration was measured onsite.

4.2.8 Water Quality

This section summarizes the surface water and groundwater resources at LANL. A more detailed summary can be found in DOE (1979), with site-specific information in LANL (1993a,c).

4.2.8.1 Surface Water

The Rio Grande is the major source of surface water in north-central New Mexico. All surface water drainage and groundwater discharge from the Pajarito Plateau ultimately arrives at the Rio Grande (DOE 1995i). The major canyons that contain reaches of perennial streams inside LANL are the Pajarito, Water, Ancho, and Chaquehui Canyons. Los Alamos, Water, and Pajarito Canyons, and perennial streams originate upstream of LANL facilities or effluent discharge points (LANL 1993d). Currently, it is not well understood how surface water flow affects perched water zones at LANL.

Perennial streams in the lower portions of Ancho and Chaquehui Canyons extend to the Rio Grande without being depleted. In lower Water Canyon, the perennial stream is very short and does not extend to the Rio Grande. In Pajarito Canyon, Homestead Spring feeds a perennial stream only a few hundred meters long, followed by intermittent flows for varying distances, depending on climate conditions (LANL 1993d).

Table 4-9. Selected Radionuclide Concentrations in the Air from and Around the Los Alamos National Laboratory (for 1992)

Radionuclide (Units)	Group Location	Number of Samples	Number Above Detection	Maximum ^(a)	Minimum ^(a)	Mean ^(a)
H-3 (pCi/m ³)	Regional	45	1	3.6 (1.0)	-3.0 (2.3)	0.3 (6.4)
	Perimeter	193	69	11.8 (2.0)	-11.5 (6.9)	2.7 (17.3)
	Onsite	184	80	68.2 (4.5)	-3.7 (1.9)	6.1 (26.4)
	Waste Sites	61	38	685.0 (205)	-1.1 (0.5)	42.8 (34.7)
U-234 (aCi/m ³)	Regional	12	12	82.8 (6.5)	10.8 (6.0)	30.6 (19.2)
	Perimeter	56	53	43.1 (4.7)	2.6 (4.2)	12.8 (43.6)
	Onsite	55	49	52.2 (4.7)	0.0 (6.9)	13.8 (44.9)
	Waste Sites	19	18	32.4 (5.3)	2.1 (5.6)	15.4 (32.4)
U-235 (aCi/m ³)	Regional	12	3	14.2 (2.7)	0.0 (5.2)	0.2 (13.8)
	Perimeter	56	3	4.9 (1.6)	-1.1 (2.3)	0.3 (36.5)
	Onsite	55	5	6.0 (4.3)	-2.3 (3.0)	0.4 (36.1)
	Waste Sites	19	1	4.1 (2.2)	-1.2 (20.2)	0.5 (27.3)
U-238 (aCi/m ³)	Regional	12	12	80.9 (6.4)	7.3 (4.4)	28.8 (16.4)
	Perimeter	56	55	109.0 (7.1)	1.4 (1.9)	18.4 (36.0)
	Onsite	55	53	182.3 (13.0)	2.4 (1.5)	21.1 (38.7)
	Waste Sites	19	19	106.4 (17.3)	4.1 (4.2)	22.6 (25.2)
Pu-238 (aCi/m ³)	Regional	12	0	2.4 (3.3)	-1.1 (4.1)	0.6 (3.8)
	Perimeter	56	2	8.4 (4.3)	-2.7 (3.8)	1.0 (3.8)
	Onsite	55	1	3.8 (3.4)	-1.7 (7.4)	0.6 (4.1)
	Waste Sites	20	5	9.7 (3.8)	-5.2 (17.3)	1.4 (4.6)
Pu-239,240 (aCi/m ³)	Regional	12	1	4.3 (2.9)	0.4 (2.6)	1.5 (8.1)
	Perimeter	56	10	79.5 (8.3)	-0.5 (2.3)	5.9 (21.8)
	Onsite	55	7	92.0 (28.0)	-2.7 (1.7)	4.2 (20.4)
	Waste Sites	20	1	3.4 (2.3)	-0.3 (3.2)	1.1 (16.0)
Am-241 (aCi/m ³)	Regional	5	2	3.7 (4.1)	-1.6 (4.4)	1.2 (9.1)
	Perimeter	21	10	4.1 (3.1)	0.6 (4.2)	1.8 (17.9)
	Onsite	24	9	12.6 (4.6)	0.0 (3.6)	2.3 (20.0)
	Waste Sites	12	4	3.7 (6.6)	0.0 (4.8)	1.7 (15.6)
U (pg/m ³)	Regional	12	12	244.0 (19.9)	22.0 (15.4)	87.2 (54.5)
	Perimeter	56	56	325.5 (22.1)	4.6 (6.5)	55.1 (123.3)
	Onsite	55	55	544.1 (39.6)	7.2 (5.2)	63.3 (130.7)
	Waste Sites	19	19	316.5 (61.1)	12.3 (14.9)	68.0 (87.5)
I-131 (aCi/m ³)	Perimeter/Onsite	66	0	5.0 (3)	-40 (70)	1.0 (50)
(a) Uncertainties ($\pm 2\sigma$) are in parentheses.						

| Springs between 2408 and 2713 m (7900 and 8900 ft) elevation on the eastern slope of the Jemez
 | Mountains supply base flow throughout the year to the upper reaches of Canon de Valle, and to Los
 | Alamos, Pajarito, and Water Canyons. These springs discharge water perched in the Bandelier Tuff and
 | Tschicoma Formation at rates from 0.0001 to 0.0085 m³/s (0.0045 to 0.30 ft³/s) (DOE 1995i). The volume

of flow from the springs is insufficient to maintain surface flow withing more than the western third of the canyons before it is depleted by evaporation, transpiration, and infiltration into the underlying alluvium (LANL 1993d).

At least 11 drainage areas pass through the LANL eastern boundary (LANL 1992a). Runoff from heavy thunderstorms and heavy snowmelt reaches the Rio Grande several times a year from some drainages (DOE 1995i). Runoff from summer storms on the Pajarito Plateau reaches a maximum discharge in less than 2 h and has a duration generally less than 24 h (LANL 1992b). Brief downpours can cause local flash flooding, especially in canyons, streams, and other low spots. Large-scale flooding is not common in New Mexico and has never been observed in Los Alamos.

In 1993, LANL (1993b) reported an evaluation of the 100-yr, 6-h storm event (that is, probability of occurrence of 1% per year), which represented the worst-case scenario providing a conservative estimate of a 100-yr flood event in Los Alamos Canyon. However, the peak flow for this event was 25 m³/s (902 ft³/s), indicating that flooding would not likely reach the finished floor elevation of the Omega West Reactor.

4.2.8.2 Groundwater

Groundwater occurs in three modes in the Los Alamos area: 1) as water in shallow alluvium in some of the larger canyons, 2) as perched water, and 3) as the main aquifer of the Los Alamos area (LANL 1992a).

Perched water at LANL occurs in conglomerates and basalts beneath the alluvium in a limited area in the midreach of the Pueblo Canyon and in a second area near the confluence of lower Pueblo and Los Alamos canyons (LANL 1992a). The horizontal extent of the aquifer is limited. The perched water in these two locations is not known to be hydrologically connected with the main aquifer.

The main aquifer is the only aquifer capable of supplying municipal and industrial water for the LANL area (LANL 1992a). The surface water and groundwater in the alluvium are separated from water in the main aquifer by several hundred feet of unsaturated volcanic tuff and sediments. The major recharge area for the deep aquifer is in the intermountain basins formed by the Valles Caldera (DOE 1979). The saturated sediments and volcanics in the basin are highly permeable and recharge the main aquifer. The movement of the main aquifer is east-southeast toward the Rio Grande.

For more information on groundwater, refer to LANL (1992a) and DOE (1979).

4.2.9 Ecological Resources

The significant diversity of ecosystems at LANL is due partly to the dramatic 1500-m (5000-ft) elevational gradient from the Rio Grande on the east, to the Jemez Mountains 20 km (12 mi) on the west, and to the many canyons with abrupt surface slope changes that dissect the area. Ecological surveys of

LANL were carried out in 1987 and 1992; the latter study was conducted to characterize vegetation. A 1995 study was carried out to document and examine the occurrence of nesting Mexican spotted owls (Risberg 1995).

4.2.9.1 Terrestrial Resources

Several vegetative community types are found on the Pajarito Plateau and surrounding mountains. Two of them--piñon-juniper woodland and ponderosa pine forest/piñon-juniper woodland--are predominant. Others include fir, fir/aspen, pine-fir, shrub grass-fir, and juniper-grassland (Figure 4-12) (Dunham 1995). For additional information on vegetation, refer to Travis 1992.

Rocky Mountain mule deer (*Odocoileus hemionus*) and Rocky Mountain elk (*Cervus canadensis*) make up the most important and prevalent big game species at LANL. Other large mammals include American black bear (*Ursus americanus*), coyote (*Canis latrans*), and raccoon (*Procyon lotor*). Small mammals include the Mexican woodrat (*Neotoma mexicana*), deer mouse (*Peromyscus maniculatus*), Abert's squirrel (*Sciurus aberti*), and cottontail rabbit (*Sylvilagus nuttalli*) (Dunham 1995). For more information on animal life, refer to White (1981) and Risberg (1995).

4.2.9.2 Aquatic Resources

Aquatic habitats at LANL are limited to the Rio Grande and several springs and intermittent streams in the canyons; detailed descriptions of the physical aspects of the surface waters can be found in DOE (1995h). Los Alamos and Mortandad canyons have perennial flow in the lower reaches as a result of discharge of treated sanitary waste from wastewater treatment plants. Some base flow in streams in the Pajarito and Ancho canyons occurs from spring sources.

The Omega West Reactor (TA-2), located in Los Alamos Canyon, is drained by a stream less than 1 m (3.28 ft) wide that originates in the Jemez Mountains from an impounded high-elevation reservoir (2320 m). The stream channel supports little or no water-borne vegetation. The upper reaches are located in spruce-fir forests, and the lower reaches pass through mixed conifer habitat. The stream bed consists of large rocks, cobble, sand, and gravel. A wastewater outfall empties into the stream below TA-2. No fish were observed in the Los Alamos Canyon stream below the reservoir. For more information refer to Cross (1994).

4.2.9.3 Wetlands

The floodplain areas of LANL have been mapped by the U.S. Fish and Wildlife Service (Figure 4-13). For more information refer to Dunham 1995.

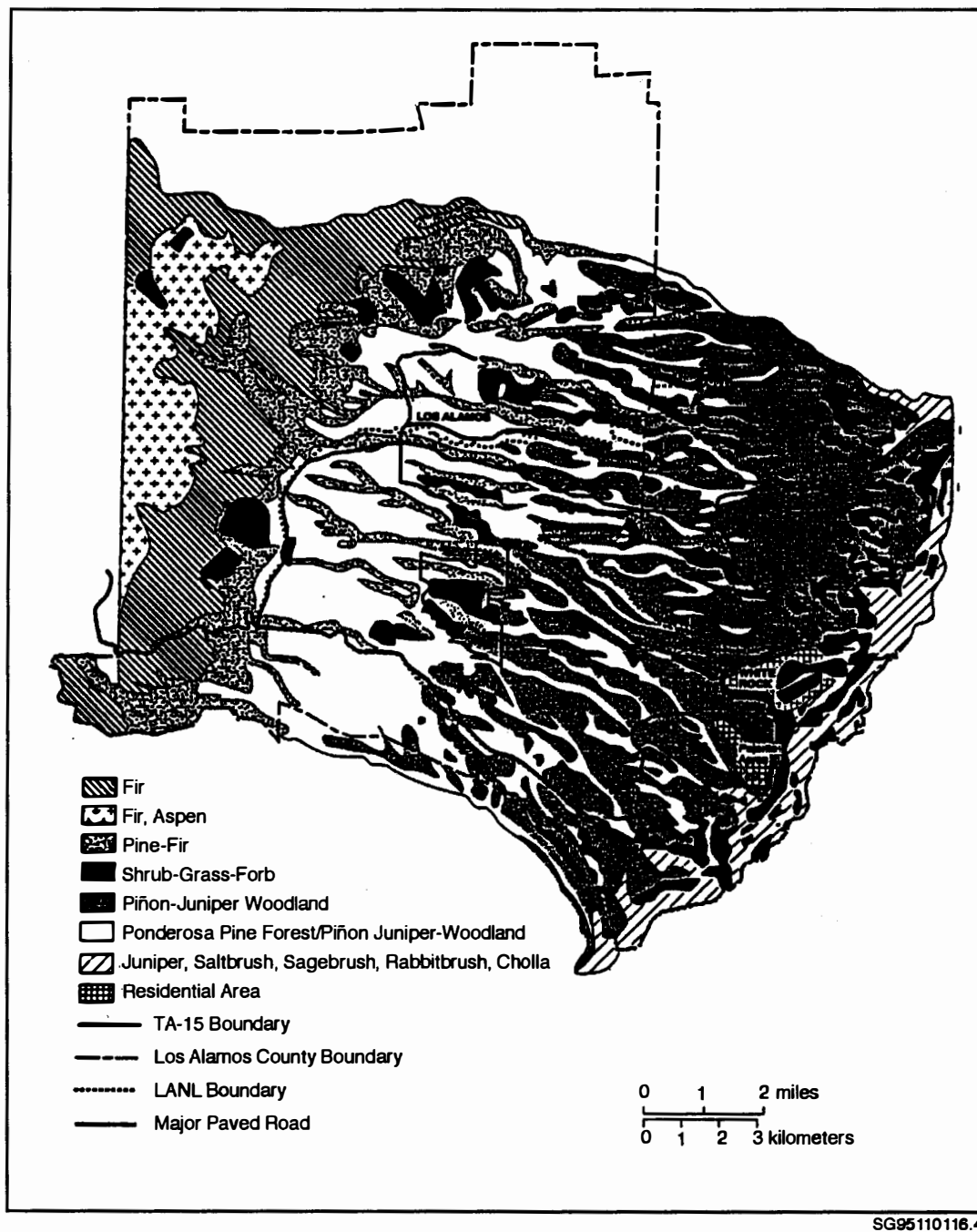


Figure 4-12. Plant Communities on the Pajarito Plateau

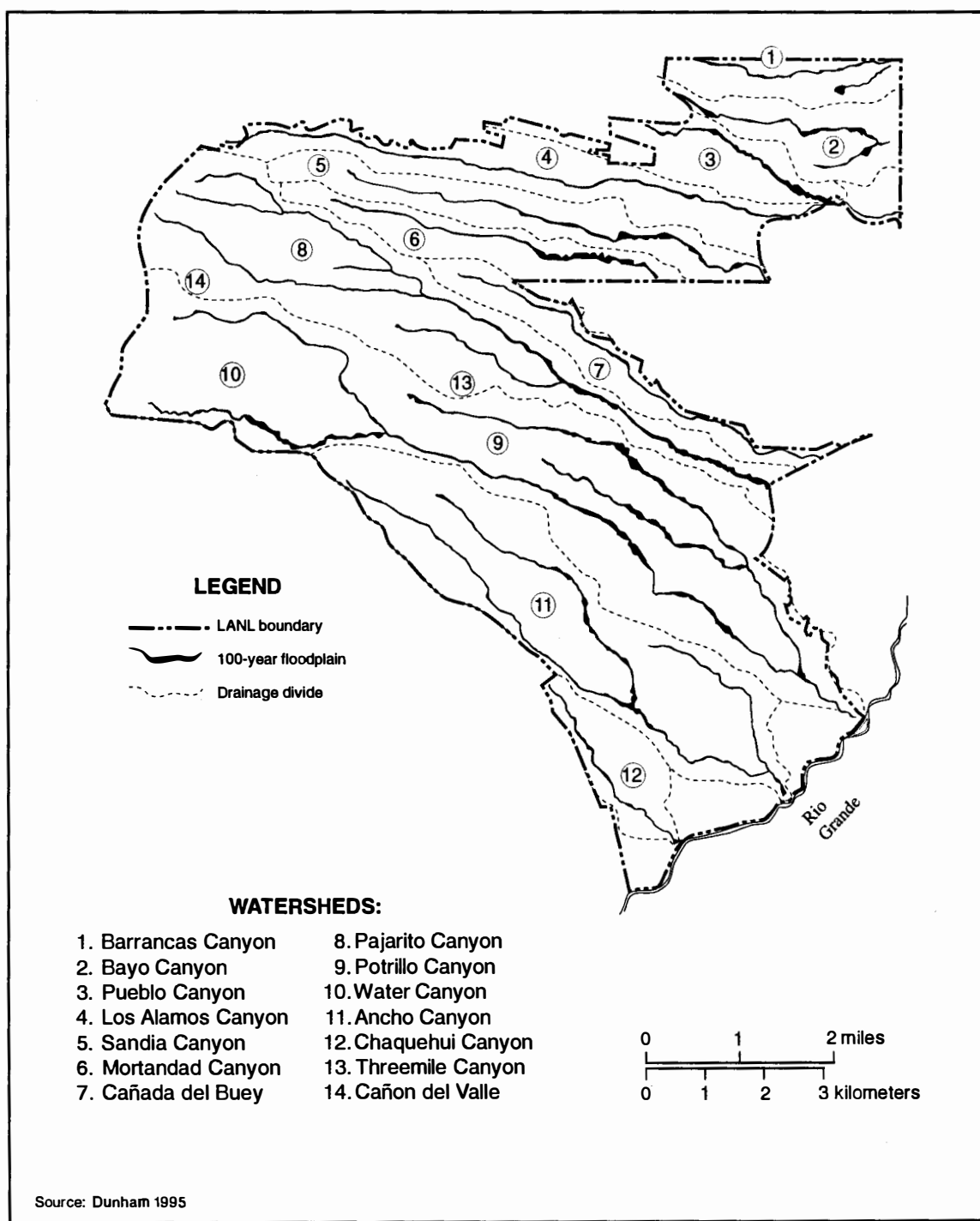


Figure 4-13. Floodplain Map of Los Alamos National Laboratory

4.2.9.4 Threatened and Endangered Species

The Mexican spotted owl is listed as a federally threatened species, and as a state endangered species in New Mexico. Canyons surrounding TA-15 and at other locations within the LANL boundaries provide nesting, roosting, and foraging habitats for the Mexican spotted owl. These owls were first observed in canyons within TA-15 by a LANL biologist with the Ecological Studies Team in the spring of 1995. These sightings were confirmed in June 1995, and a nest site was found in the TA-15 area. Two young were fledged from this nest during the 1995 breeding season (March 1 to August 31) (Risberg 1995).

A total of 11 other species that may occur at LANL are listed as threatened or endangered by either the U.S. Fish and Wildlife Service or the New Mexico Department of Game and Fish. An additional 12 species are considered candidates for inclusion on the federal endangered or threatened list or are considered rare by the State of New Mexico (Table 4-10) (DOE 1995i). The 1992 biological survey (Risberg 1995) found none of these species within LANL; however, highly suitable habitat exists for many of these species within the vicinity of the proposed project area.

4.2.10 Noise

The Omega West Reactor is located in TA-2 about 200 m from the LANL site boundary and the community of Los Alamos. Background noise levels range from 31 to 35 dB(A) in the more remote areas of the site to 51 dB(A) at the LANL site boundary which is near the community of White Rock (DOE 1995i). The increased noise level is attributed to local automobile traffic.

4.2.11 Transportation

This section describes the regional and local transportation infrastructure affected by the alternatives involving LANL. Included are descriptions of the highway and air transportation infrastructure that would be used to support production of Mo-99 at LANL. No rail shipments are planned to support production of Mo-99.

4.2.11.1 Roadways

Regional and local transportation routes in the vicinity of LANL are illustrated in Figures 4-14 and 4-15. The highway route from Albuquerque consists of Interstate 25 to Santa Fe, US 84/285 from Santa Fe to Pojoaque, and New Mexico State Highway 4 from Pojoaque to Los Alamos. New Mexico State highways 14 and 44 are also significant roadways in the region surrounding LANL.

Estimates of baseline traffic volume for road segments providing access to LANL were not available. Traffic estimates for Los Alamos County, based on traffic surveys and site employee surveys, approximate travel distances per day within the county at 64 km (46 mi). Of this total, LANL employees commuting onsite and to and from work account for approximately two-thirds or 49 km (33 mi) of the total distance.

Table 4-10. Threatened, Endangered, and Candidate Species Potentially Present at Los Alamos National Laboratory

Scientific Name	Common Name	Status	Habitat	Potential for Occurrence
PLANTS				
<i>Fritillaria atropurpurea</i>	Checker lily ^(a)	SE ^(d)	Mixed conifer	Low to Moderate
<i>Lilium philadelphicum</i>	Wood lily ^(a)	SE ^(d)	Ponderosa to mixed conifer, cliffs 1829 to 3048 m (6000 to 10,000 ft)	Low to Moderate
<i>Mammillaria wrightii</i>	Wright's fishhook cactus ^(a)	SE ^(d)	Desert grassland to piñon-juniper 914 to 2134 m (3000 to 7000 ft)	Unlikely to Low ^(h)
<i>Opuntia viridiflora</i>	Santa Fe cholla ^(a)	FC ^(e) , SE ^(d)	Piñon-juniper 2195 to 2438 m (7200 to 8000 ft)	Unlikely to Low ^(h)
<i>Pediocactus papyracanthus</i>	Grama grass cactus ^(a,b)	FC ^(e)	Grasslands, piñon-juniper woodlands 1524 to 2225 m (5000 to 7300 ft)	Unlikely to Moderate ⁽ⁱ⁾
ANIMALS				
<i>Plethodon neomexicanus</i>	Jemez Mountain salamander ^(b)	FC ^(e) , SE ^(f)	Densely wooded, shady canyons	Unlikely to Low
<i>Accipiter gentilis</i>	Northern goshawk ^(a,b,c)	FC ^(e)	Ponderosa; dense, mature, or old-growth coniferous forest	Low to Moderate
<i>Buteo regalis</i>	Ferruginous hawk ^(h)	FC ^(e)	Grasslands	Unlikely to Low ^(h)
<i>Buteogallus anthracinus</i>	Common black hawk ^(c)	SE ^(f)	Riparian with cottonwood	Unlikely ^(h)
<i>Cynanthus latirostris</i>	Broad-billed hummingbird ^(a,b)	SE ^(f)	Riparian woodlands	Unlikely ^(h)
<i>Empidonax traillii eximius</i>	Southwestern willow flycatcher ^(a)	FE ^(e) , SE ^(f)	Riparian woodlands dominated by cottonwoods 1147 to 2759 m (3700 to 8900 ft)	Unlikely ^(h)
<i>Falco peregrinus</i>	Peregrine falcon ^(a,b,c)	FE ^(e) , SE ^(f)	Ponderosa-piñon, streams and lakes	Low
<i>Haliaeetus leucocephalus</i>	Bald eagle ^(a,b,c)	FE ^(e) , SE ^(f)	Riparian near streams and lakes	Unlikely to Low ^(h)
<i>Ictinia mississippiensis</i>	Mississippi kite ^(a)	SE ^(g)	Riparian and shelterbelts	Unlikely ^(h)

Table 4-10. (contd)

Scientific Name	Common Name	Status	Habitat	Potential for Occurrence
<i>Lanius ludovicianus</i>	Loggerhead shrike ^(b)	FC ^(e)	Grasslands, open woodland	Unlikely to Low ^(h)
<i>Plegadis chihi</i>	White-faced ibis ^(b)	FC ^(e)	Streams, marshes, ponds	Unlikely ^(h)
<i>Strix occidentalis lucida</i>	Mexican spotted owl ^(a,b,c)	FT ^(e)	Mixed conifer; mountains and canyons, uneven-aged, multi-storied forest with closed canopy	High
<i>Euderma maculatum</i>	Spotted bat ^(a,b,c)	FC ^(e) , SE ^(f)	Ponderosa, piñon-juniper, cliffs and rock crevices	Low
<i>Myotis evotis</i>	Long-eared myotis ^(a)	FC ^(e)	Spruce-fir community	High
<i>Myotis lucifugus occultus</i>	Occult little brown bat ^(b)	FC ^(e)	Mountains, caves, and hollow trees	Unlikely ^(b)
<i>Myotis thysanodes</i>	Fringed myotis ^(a)	FC ^(e)	Water bodies at various elevations	High
<i>Myotis volans</i>	Long-legged myotis ^(a)	FC ^(e)	Ponderosa pine and higher elevations, water bodies	High
<i>Myotis yumanensis</i>	Yuma myotis ^(a)	FC ^(e)	Permanent watercourses	High
<i>Ochotona princeps nigrescens</i>	Goat peak pika ^(b)	FC ^(e)	Lava boulders	Unlikely ^(b)
<i>Zapus hudsonius luteus</i>	New Mexican jumping mouse ^(b)	FC ^(e) , SE ^(f)	Near streams and vegetation	Low

(a) Source: Dunham 1995.

(b) Source: DOI 1995a.

(c) Source: Risberg 1995.

(d) From New Mexico Energy, Minerals and Natural Resources Department, NMFRCD Rule No. 91-1.

(e) Source: DOI 1995b.

(f) From New Mexico Department of Game and Fish, Regulation #682, 11/30/90.

(g) Until recently, listed as state endangered by the New Mexico Department of Game and Fish.

(h) Suitable habitat for this species does not occur in the proposed project area (Risberg 1995).

Status:

SE: State Endangered: New Mexico-listed species protected as threatened or endangered under the Wildlife Conservation Act.

FC: Federal Candidate "...[any species] for which the USFWS has on file enough substantial information of biological vulnerability and threat, [or] for which other information now in the possession of the USFWS indicates that proposing to list them as threatened or endangered is possibly appropriate..." [Federal Register Vol. 56, No. 255].

FE: Federal Endangered: "...any species that is in danger of extinction throughout all or a significant portion of its range." [Federal Register Vol. 56, No. 255].

FT: Federal Threatened: "...any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." (Endangered Species Act of 1973).

Table 4-10. (contd)

Potential for Occurrence:

Unlikely – Suitable habitat for species does not exist within or near operable unit.

Low – Potential for occurrence due to habitat requirements, but not found during field survey or not known to occur in general project area.

Moderate – Known to occur in habitat similar to project area or general area of operable unit.

High – Species observed during field survey or known populations exist near project area.

Note: Potential for occurrence sometimes given as a range, due to variations in findings by different researchers at various times.

4.2.11.2 Airports and Air Traffic

Three airports are located in the vicinity of the LANL: LANL Airport, Albuquerque International Airport (135 km/83.8 mi from LANL), and Santa Fe Airport (32 km/20 mi from LANL). LANL airport is owned by the DOE and managed by the Zia Company (DOE 1979) and is typically used for non-jet traffic. Figure 4-14 shows the locations of Albuquerque International Airport and Santa Fe Airport with respect to LANL and interconnecting roadways.

4.2.12 Radiological Health and Safety

For general information applicable to the four alternatives, refer to Section 3 of this EIS.

4.2.12.1 Current Radiological Environment

Normal operations at LANL produce radioactive air emissions (LANL 1995). Air emissions are routinely sampled from 88 release points. The major source of radioactive emissions is the Los Alamos Meson Physics Facility, which releases short-lived (8-s to 20-min half-life) air activation products and tritium. The quantity released depends on the amount of time the facility is in operation. In 1994, the Los Alamos Meson Physics Facility released 52,000 Ci of tritium and mixed air activation products. The maximally exposed individual, located across a canyon north of the Los Alamos Meson Physics Facility, received an estimated dose of 7.6 mrem in 1994 (LANL 1995).

The total uranium-235 released from LANL as a whole was 0.38 mCi. An individual located about 1000 m (0.6 mi) north of the Chemistry and Metallurgy Research Facility, in Los Alamos townsite, receives a potential annual dose of 2.7×10^{-3} mrem from the Chemistry and Metallurgy Research Facility operations.

Naturally occurring background radiation dose in Los Alamos is 340 mrem/yr. A gamma ray reading (measured using a thermoluminescent detector) on 48th Street, the Los Alamos neighborhood nearest to the Chemistry and Metallurgy Research Facility, was 105 mrem, compared with readings from Santa Fe, Espanola, and Pojoaque that ranged from 92 to 97 mrem (LANL 1994a).

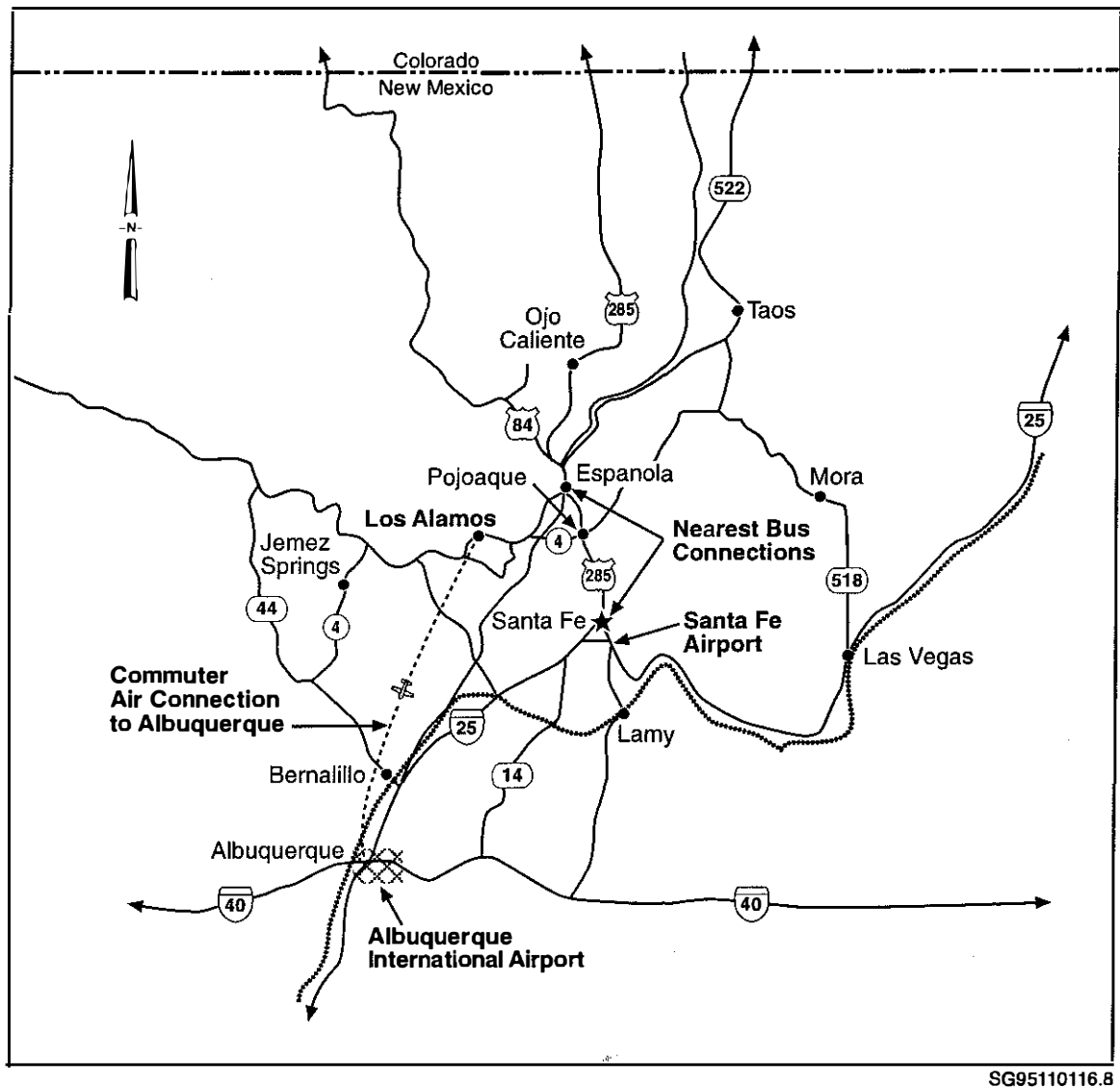


Figure 4-14. Regional Transportation Routes Near Los Alamos National Laboratory

In 1993, the effective dose equivalent to the maximally exposed individual from LANL operations was 5.6 mrem (5.6×10^{-5} Sv). This dose includes the contribution from non-point sources. The location of the maximally exposed individual is at a business office 800 m (0.5 mi) north-northeast of the site boundary of TA-53.

The collective dose for workers at the LANL site in 1993 amounted to 239 person-rem. Fewer than one (0.1) latent cancer fatalities are expected from this worker dose. The estimated collective dose for the population within 80 km (50 mi) of the LANL site was 4.0 person-rem for 1994 (LANL 1995). No (0.002) excess latent cancer fatalities are expected from this population dose. The annual collective

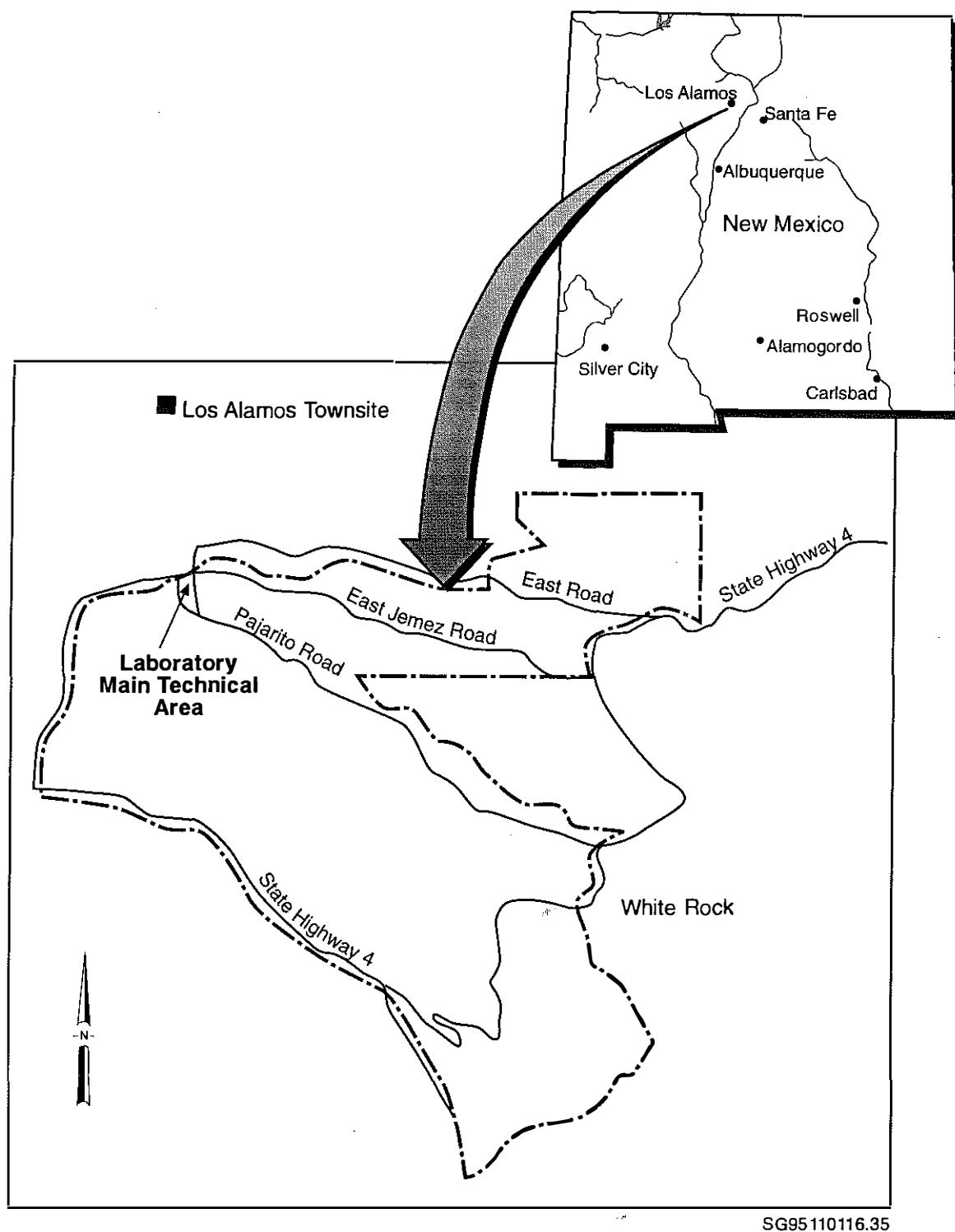


Figure 4-15. Local Transportation Routes Near Los Alamos National Laboratory

population dose for the same population from naturally occurring background radiation would be about 110,000 person-rem/yr (DOE 1995i).

4.2.13 Site Services

The LANL utility system has 640 km (400 mi) of lines that provide electricity, telecommunications, water, sanitary sewer, radioactive liquid waste disposal, and natural gas distribution within the laboratory. Existing resource requirements are summarized in Tables 4-11 and 4-12.

Table 4-11. Existing Los Alamos National Laboratory Utility Resource Requirements

Utility Resources	Average Daily Consumption	Peak Demand	System Capacity
Electricity	1045 MWh	87 MW ^(a)	120 MW
Natural Gas	4,200,000 ft ³	417,000 ft ³ /hr	500,000 ft ³ /hr
Water	4,100,000 gal	6600 gpm	6900 gpm
(a) MW is megawatt. Conversions: To convert cubic feet (ft ³) to cubic meters (m ³), multiply by 0.028317. To convert gallons (gal) to liters (L), multiply by 3.785.			

Table 4-12. Existing Los Alamos National Laboratory Chemical Resource Requirements

Chemical Resources	Total Annual Consumption	Storage Capacity
Liquid Nitrogen	1,189,000 gal	5500 gal
Argon	11,486,000 ft ³	1,125,000 ft ³
Helium	1,066,000 ft ³	67,000 ft ³
Hydrogen	35,000 ft ³	1100 ft ³
Oxygen	5,057,000 gal	135,000 gal
Carbon Dioxide	686,000 ft ³	96,200 ft ³
Conversions: To convert cubic feet (ft ³) to cubic meters (m ³), multiply by 0.028317. To convert gallons (gal) to liters (L), multiply by 3.785.		

Electricity is supplied to LANL by a Los Alamos County/DOE power pool over two 115-kV lines (one from Santa Fe and one from Albuquerque). Natural gas used by the laboratory comes from the San Juan Basin in northwest New Mexico. The lines are operated and maintained by the Gas Company of New Mexico under contract to DOE. Water for the laboratory and adjacent area (including Los Alamos townsite, White Rock, and Bandelier National Monument) primarily comes from three DOE-operated well fields. The existing LANL sanitary sewer system includes two treatment facilities. In addition, approximately 780 septic tanks are dispersed throughout laboratory areas not served by the existing sanitary sewer system.

4.2.14 Waste and Spent Nuclear Fuel Management

Ongoing activities and operations generate waste from processing effluents, separating isotopes, manufacturing, testing and manufacturing explosives, cleaning chemically contaminated equipment, working with radioactive materials, and through research and development programs in basic and applied chemistry. Waste types generated include radioactive waste (transuranic waste, low-level radioactive waste, and low-level mixed waste), hazardous chemical waste, biological waste, medical waste, and sanitary solid and liquid waste. LANL generates no high-level waste. Some spent nuclear fuel is kept in interim storage. The laboratory has initiated an effort to minimize the generation of radioactive and hazardous chemical waste (DOE 1995k).

4.2.14.1 Spent Nuclear Fuel

Omega West Reactor is currently shut down. The reactor contains no fuel, and all of the 86 elements are in temporary dry storage at the Chemistry and Metallurgy Research Facility. Additional reactor sites and facilities at Los Alamos, such as the Fast Burst Reactor and General Purpose Critical Assembly, each contain some radioactive and fissionable materials, but do not routinely produce spent nuclear fuel. The quantity of spent nuclear fuel at LANL in 1995 was estimated as 14 kg (heavy metal) (DOE 1995g).

4.2.14.2 Low-Level Radioactive Waste

Liquid low-level waste is generated from many areas throughout LANL. LANL has two onsite liquid low-level waste treatment facilities, a chemical treatment and ion-exchange plant, and a chemical treatment plant. Solid low-level waste (paper, plastic, glassware, rags) is packaged and transported to an onsite location (at TA-54, Area G) for compaction and burial. In 1991, approximately 21,903,795 L (5,787,000 gal) of liquid low-level waste and 5701 m³ (7541 yd³) of solid low-level waste were generated (DOE 1993b). The cumulative volume of low-level waste onsite, as of 1993, is 220,700 m³ (288,545 yd³) with a 1993 annual production volume of 2100 m³ (2746 yd³) (DOE 1994a).

4.2.14.3 Low-Level Mixed Waste

Low-level mixed waste at LANL includes solvents, pyrophoric substances, spray cans, scintillation vials, miscellaneous reagent chemicals, vacuum pump oil contaminated with mercury, and other

contaminated material. LANL does not permanently dispose of low-level mixed waste onsite. The waste is stored at TA-54 and at Areas L and G. All low-level waste mixed packages are planned to be transported by commercial carriers to a permitted, licensed facility. In 1991, LANL generated 34,110 L (9000 gal) of liquid mixed waste and 112 m³ (148 yd³) of solid mixed waste (DOE 1993b). As of 1993, LANL had a cumulative volume of 4681.6 m³ (6121 yd³) of low-level mixed waste (DOE 1994a).

4.3 Oak Ridge Environment

4.3.1 Overview

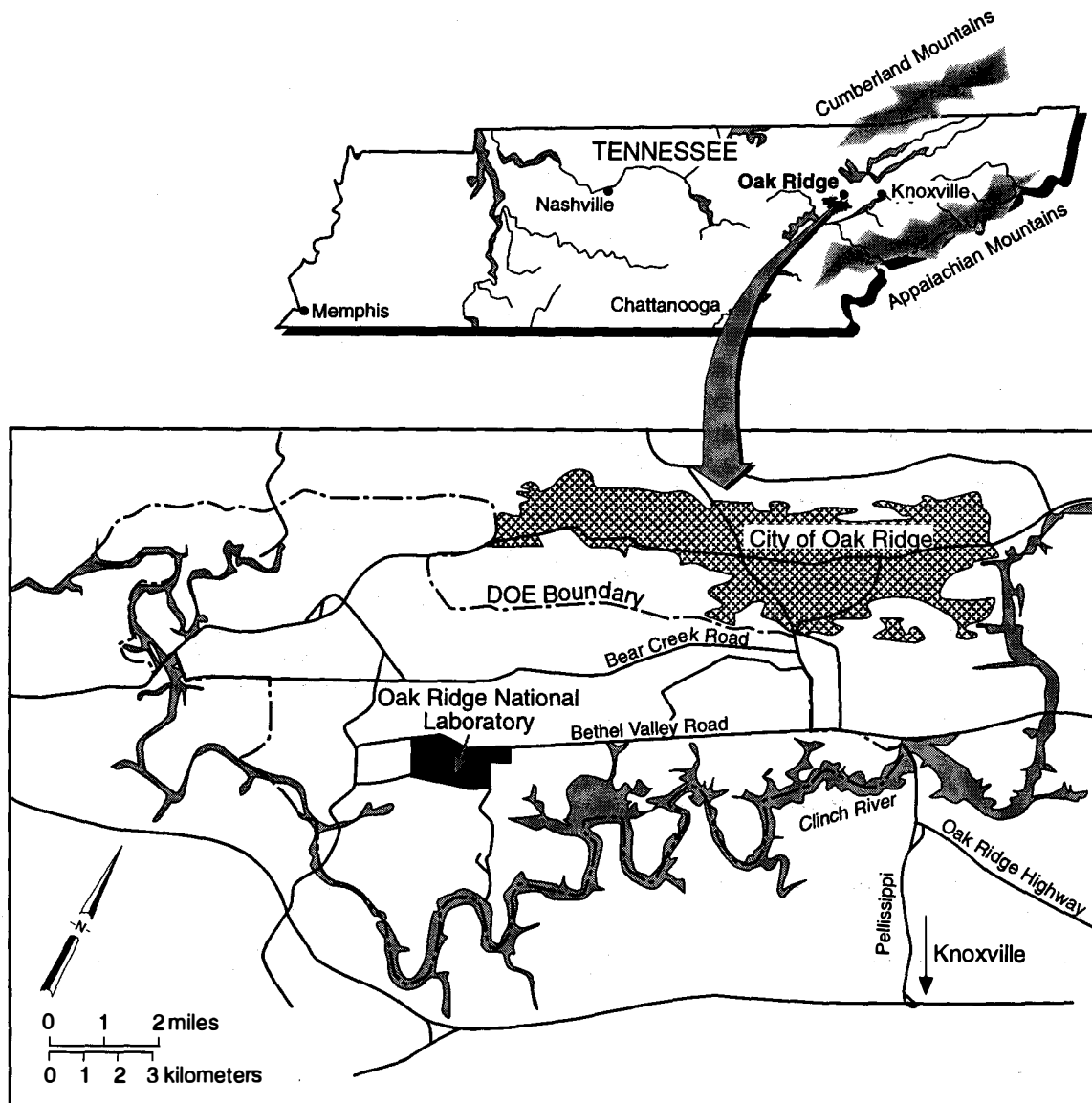
The city of Oak Ridge and the Oak Ridge Reservation lie between Roane and Anderson counties in a predominantly rural area in northeastern Tennessee and are situated between the Cumberland and Southern Appalachian mountain ranges (Figure 4-16). The Clinch River borders the city on the south, flowing in a general east-to-west direction, with many streams along the southern boundary of the city. Knoxville is located approximately 40 km (25 mi) southeast of Oak Ridge and is the largest city in the area.

The Oak Ridge Reservation is located on 140 km² (54 mi²) of federally owned land adjoining the city limits of Oak Ridge, Tennessee. Land use activities within the Oak Ridge Reservation consist of three main plant sites: the Y-12 Plant (3.4 km²/1.3 mi²), the Oak Ridge National Laboratory (ORNL) (4.7 km²/1.8 mi²), and the K-25 site (2.8 km²/1.1 mi²). A number of reactors have been built on the Oak Ridge Reservation, including the Oak Ridge Research Reactor that is being considered as an option for the production of Mo-99. The site also supports research into energy conservation, fusion, and other energy technologies.

Land uses bordering the Oak Ridge Reservation are primarily forest and agricultural. Residential and commercial are the only other significant uses of land in the vicinity and occur along the northeast and northwest boundaries of the Oak Ridge Reservation in the city of Oak Ridge. The land areas bordering the Oak Ridge Reservation consist of woodlands, small farms, and rural residences (Figure 4-17).

Although the Oak Ridge area experiences a moderate level of seismic activity, the largest recorded earthquake in this area occurred in Giles County, Virginia, on May 31, 1897, and registered magnitude 5.8 on the Richter scale. The most recent significant earthquake in the Appalachian area occurred on November 30, 1973, at Maryville, Tennessee, 34 km (21 mi) southeast of the Oak Ridge Reservation. This earthquake had a Modified Mercalli Intensity of VII at the epicenter and a Modified Mercalli Intensity of V to VI in the Oak Ridge area.

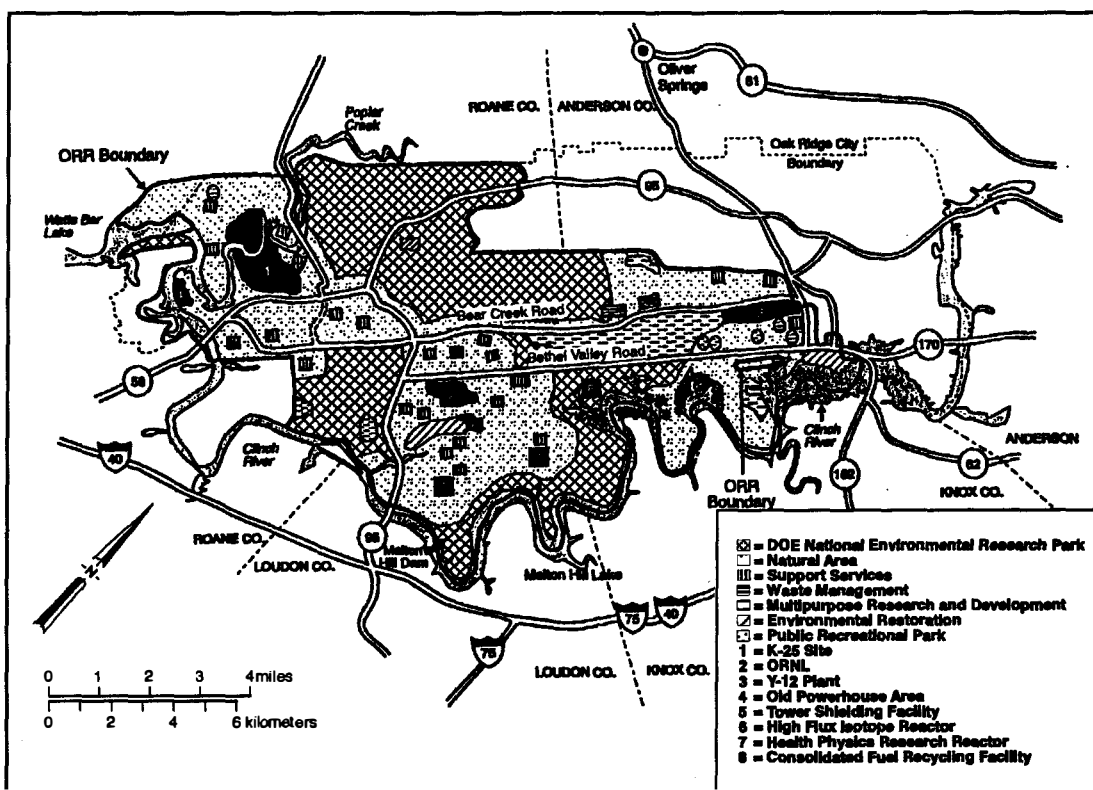
Of the total federal- and state-listed threatened, endangered, or other special-status species designated by the Endangered Species Act or the state's Nongame and Endangered Species and the Rare Plant Protection and Conservation Laws, 25 species have recent records of occurrence on the Oak Ridge Reservation. The potential occurrence of another 22 species has been determined based on historical records, proximity to geographic ranges, and the migratory nature of species. No animal species listed by the



SG95110116.14

Figure 4-16. Location of Oak Ridge National Laboratory

federal government as threatened or endangered are known to reside on the Oak Ridge Reservation. However, the bald eagle (*Haliaeetus leucocephalus*, federal endangered) is a winter visitor to Watts Bar Lake and Melton Hill Lake. No critical habitat for threatened and endangered species, as defined in the Endangered Species Act, exists on the Oak Ridge Reservation.



SG95110116.34

Figure 4-17. Land Use for the Oak Ridge Reservation

The total mass of spent nuclear fuel at ORNL is approximately 21 tons. The total mass of spent nuclear fuel at Y-12 Plant is approximately 3.5 tons. The Y-12 Plant, K-25 site, and the ORNL generate and manage low-level wastes. The total cumulative volume of low-level waste disposed of through 1993 was 442,000 m³ (577,874 yd³).

4.3.2 Land Use

4.3.2.1 Oak Ridge Reservation

The Oak Ridge Reservation is located on approximately 140 km² (54 mi²) of federally owned land adjoining the city limits of Oak Ridge, Tennessee (MMES 1989a). Land use activities at the Oak Ridge Reservation have historically occurred within the boundaries of three main plant sites. These are the Y-12 Plant (3.4 km²/1.3 mi²), the ORNL (4.7 km²/1.8 mi²), and the K-25 site (2.8 km²/1.1 mi²) (Figure 4-17). Other Oak Ridge Reservation lands were used for waste storage in the mid-1940s and for environmental research in the 1950s. A forestry management program was initiated in 1964, and the first comprehensive forest management program was released in 1965. The Oak Ridge Reservation has been used by research institutions, universities, and government agencies as a site for the study of terrestrial ecology, aquatic

ecology, forestry, and agriculture. In 1980, the DOE designated approximately 54 km² (21 mi²) of undeveloped Oak Ridge Reservation land as a National Environmental Research Park (see Figure 4-17) that provides protected land areas for research and education in the environmental sciences (MMES 1989a).

Land use outside the three main plant sites falls into seven general categories: multipurpose research and development, support services, waste management, environmental restoration, natural areas, public recreational park, and national environmental research park (Figure 4-17). Approximately 58% of the land on the Oak Ridge Reservation (8121 ha/20,059 ac or 80 km²/31 mi²) can be classified as undeveloped (MMES 1994).

4.3.2.2 Oak Ridge National Laboratory

The ORNL is located in the southern portion of the Oak Ridge Reservation, just south of Bethel Valley Road, about 0.5 mi east of State Route 95. ORNL is surrounded by a natural area, with sites and facilities dedicated to environmental restoration and nearby support services. Approximately 5 km (3 mi) south of the ORNL is the Melton Hill Dam, which controls the flow of the Clinch River near the Oak Ridge Reservation. The primary function of Melton Hill Dam is power generation; flood control is a secondary function (Figure 4-18) (DOE 1995l).

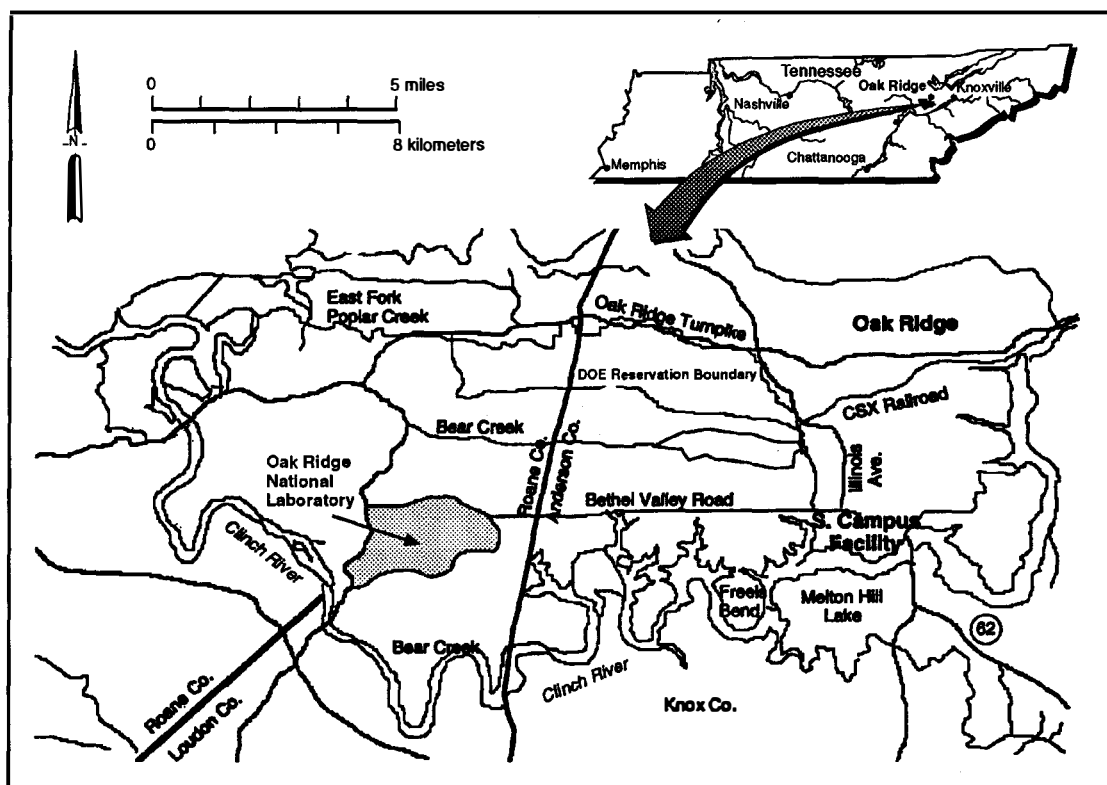
Land use at the ORNL site is dedicated to the mission of the laboratory. ORNL has a number of reactors, including the Oak Ridge Research Reactor under consideration as an option for the production of Mo-99. The site also supports research in energy conservation, fusion, and other energy technologies, as well as research in the physical and life sciences (DOE 1994c).

4.3.3 Socioeconomic Environment

The region of influence for the Oak Ridge Reservation has been well-established in numerous previous environmental assessments and environmental impact statements for site facilities, and includes the counties of Anderson, Knox, Loudon, Morgan, and Roane and the major cities located in those counties. This region of influence is defined as the region in which most of the direct and indirect socioeconomic effects of the proposed Oak Ridge Research Reactor could be expected to impact local populations and institutions. It was estimated that about 92% of Oak Ridge Reservation employees commute to the Oak Ridge Reservation from residences in these counties. It was assumed that whatever resources and utilities are needed to modify and operate the Oak Ridge Research Reactor for production of Mo-99 are available within this region of influence (DOE 1995m).

4.3.3.1 Demographic Characteristics

The population of the region of influence was almost 500,000 at the time of the 1990 census. Between 1980 and 1990, the population grew by 4.0%. The city of Oak Ridge has been losing population since 1970, and Anderson County, in which Oak Ridge is predominately located, is expected to decline slightly



SG95110116.17

Figure 4-18. ORNL and Surrounding Area (DOE 1995m)

in population between 1990 and 2000. The East Tennessee Development District is forecasting a 3.1% growth for the region of influence between 1990 and 2000 (East Tennessee Development District 1995a). This forecast reflects, in large measure, the current and projected reduction in activities and work force at various Oak Ridge facilities by DOE and its contractors.

On average, compared with the state of Tennessee, the region of influence has a smaller proportion of its population under 18 years and a larger proportion of its population under 65 years. The dependency ratio, which indicates approximately how many dependents each 100 persons in the productive years must support, is somewhat lower for the region of influence than the state as a whole, largely due to Knoxville's higher proportion of working age persons in its population.

The racial and ethnic composition of the region of influence differs markedly from the state of Tennessee, with 92% white in the region of influence versus 83% for the state. The Hispanic population, at 0.6%, is quite low compared with the state as a whole (University of Tennessee - Knoxville 1994).

Population in the region of influence is on average more highly educated than the average state population. This situation reflects the high educational attainment of the Oak Ridge Reservation labor

force and the presence of Knoxville in the region of influence. Median household incomes and per capita personal income are higher in both Anderson and Knox counties than for the state of Tennessee. Except for Morgan and Roane counties, the region of influence has a lower percentage of persons living below the poverty level than is true for the state as a whole.

4.3.3.2 Economic Base

The total 1994 labor force in the region of influence was 287,491, a 13.9% increase since 1991 (East Tennessee Development District 1995b). Unemployment declined during that period from 12,913 persons to 10,400 persons, for a 19.5% decline. Using different sources, Table 4-13 shows employment by industry in 1990 and 1993 for the five counties, and the region of influence and the state of Tennessee. The unemployment rate declined from 5.1% to 3.6% during that period. In 1993, the region of influence had 317,809 employed workers who earned \$8.3 billion in wages, an increase from 299,238 employed in 1990 who earned \$6.7 billion in wages (DOC 1995). The largest gains in employment between 1990 and 1993 occurred in three industry sectors: agricultural services (17.3%), construction (17.7%), and services (15.5%). Total employment, earnings, and per capita income for the region of influence (minus Morgan County) are projected to increase 5.6%, 5.9%, and 10.5% respectively between 1995 and 2000. In the city of Oak Ridge, the percentage of workers in the three occupational categories of executive/administrative/managerial, professional, and technicians/related support substantially exceeded the proportions represented in the state of Tennessee (Oak Ridge Chamber of Commerce 1995).

Annual retail sales in the region of influence increased 13.9% between 1992 and 1994, from \$4.5 billion to \$5.1 billion dollars. Similar gains were experienced in each of the five component counties in the region of influence (East Tennessee Development District 1995c).

DOE-related employment associated with the Oak Ridge Field Office totaled 18,565 employees with a total payroll of \$841.4 million as of December 1994 (DOE 1995n). The region of influence contains 92.2% of the DOE employees at the Oak Ridge Reservation, and Anderson and Knox counties account for 78.5%.

The important economic issue for the region of influence is how current programmatic cutbacks in the DOE are likely to impact these employment and payroll levels in the area. Although little uncertainty is present about the impending cuts in level of employment at the Oak Ridge Reservation, the magnitude and timing of these cuts remains very uncertain.

4.3.4 Cultural Resources

Aboriginal occupation of the region extends back several millennia. No known archaeological or Native American traditional properties are adjacent to the Oak Ridge Research Reactor. The reactor itself has not been recorded as a historic property and has not been evaluated for its eligibility to the National Register of Historic Places.

Oak Ridge, on May 31, 1897, and registered magnitude 5.8 on the Richter scale. The most recent significant earthquake to occur in the Appalachian area occurred on November 30, 1973, at Maryville, Tennessee, 34 km (21 mi) southeast of the Oak Ridge Reservation (Beavers et al. 1982). This earthquake had an estimated Modified Mercalli Intensity of VII at the epicenter and a Modified Mercalli Intensity of V to VI in the Oak Ridge area.

Although the Oak Ridge area experiences a moderate level of seismic activity, no deformation of recent surface deposits has been detected at Oak Ridge Reservation, and seismic shocks from the surrounding, more seismically active areas are dissipated by distance from the epicenters (Boyle et al. 1982). A maximum horizontal ground surface acceleration of 0.19 g at Oak Ridge Reservation is estimated to result from an earthquake that could occur once every 2000 years (DOE 1994d).

4.3.7 Air Quality

Climatologically, the Oak Ridge Reservation is situated near the boundary between a "humid subtropic" and a "humid continental warm summer climate" (Critchfield 1974). A brief characterization of the climate is presented in Appendix D. Airborne discharges from the DOE Oak Ridge Facilities are subject to regulations issued by the U.S. Environmental Protection Agency and the Tennessee Department of Environment and Conservation Air Pollution Control Board, as well as by DOE Orders. Radioactive emissions are regulated by U.S. Environmental Protection Agency Region IV under the Clean Air Act (CAA) NESHAP, 40 CFR 61, Subpart H. DOE regulations governing airborne emissions are established in DOE Orders 5400.1 and 5400.5.

4.3.7.1 Nonradiological Air Quality

The Oak Ridge Reservation is located in Anderson and Roane counties, in the Eastern Tennessee-Southwestern Virginia Interstate Air Quality Control Region 207 (DOE 1995b). As of 1993, the areas within this air quality control region were designated as attainment with respect to all National Ambient Air Quality Standards (40 CFR 81.329).

One Prevention of Significant Deterioration ambient air quality Class I area can be found in the vicinity of Oak Ridge Reservation. That is the Great Smoky Mountains National Park, located approximately 48 km (30 mi) southeast of the Oak Ridge Reservation. Since the promulgation of the Prevention of Significant Deterioration regulations, no such permits have been required for any emissions source at the Oak Ridge Reservation.

Ambient air quality within and near the Oak Ridge Reservation was monitored until August 1990 (MMES 1993) for total suspended particulates, particulate matter less than 10 microns in diameter (PM₁₀), fluorides, lead, and sulfur dioxide.

4.3.7.2 Radiological Air Quality

Of the ambient air monitoring stations on the perimeter of the Y-12 Plant, 12 stations routinely monitor total suspended uranium particulate. The ORNL perimeter monitoring network consists of four stations that monitor radiation parameters (that is, gross alpha, gross beta, iodine, and gamma-emitting radionuclides). Samples of atmospheric tritium are also collected monthly at selected perimeter stations.

Annual data summaries are presented in Table 4-14 (MMES 1992). The data are divided into three groups. The ORNL perimeter air monitor stations are designed to collectively assess the specific impact of ORNL on the local air quality. The reservation perimeter air monitoring stations assess the impact of the entire Oak Ridge Reservation on air quality. Comparing these two data sets provides insight into the relative impact of ORNL upon the local air quality, as compared with other facilities on the reservation. The regional air monitor stations provide information on reference concentrations of isotopes and gross parameters for the region. It is highly unlikely that radionuclide concentrations at the regional air monitor stations are impacted by the operations at ORNL or the Oak Ridge Reservation. The net impact of ORNL and the Oak Ridge Reservation upon the regional air quality can be assessed by comparing the ORNL and Oak Ridge Reservation data with the regional air monitor station data. Only those values determined significantly different from zero were included in the data calculation.

4.3.8 Water Quality

This section summarizes the surface water and groundwater resources at ORNL. A more detailed summary can be found in DOE (1995b) and Solomon et al. (1992), with site-specific information in Boyle et al. (1982).

4.3.8.1 Surface Water

The Clinch River is the major surface water source receiving discharges from the Oak Ridge installations (DOE 1995b). Four Tennessee Valley Authority reservoirs influence the flow or water levels of the lower Clinch River: Norris and Melton Hill Reservoirs on the Clinch River, and Watts Bar and Fort Loudon lakes on the Tennessee River. The Oak Ridge Reservation is bounded on the south and west by a 63-km (39-mi) stretch of the Clinch River. Melton Hill Dam is located at Clinch River kilometer 37.2 (river mile 23), forming the Melton Hill Reservoir and several major embayments that bound the Oak Ridge Reservation. Both groundwater and surface water are drained from the Oak Ridge Reservation by a network of small tributaries of the Clinch River. Surface water at each of the three DOE facilities affects a different subbasin of the Clinch River. The ORNL drains into White Oak Creek and the Melton Branch, with all water that drains from the Oak Ridge Reservation entering the Clinch River and, subsequently, the Tennessee River (MMES 1989b). Heavy precipitation in the area causes localized flooding, primarily in the city of Oak Ridge (MMES 1994) and along the Clinch River. Stream flow on the Oak Ridge Reservation varies primarily with seasonal precipitation (MMES 1994). Precipitation varies throughout

Table 4-14. 1992 Radionuclide Concentrations in the Air Around Oak Ridge National Laboratory

Area	Radionuclide	Number Detected/Number of Samples	Concentration (10^{15} uCi/mL) of Detected Values				
			Max	Min	Avg	Standard Error	DCG (%)
ORNL PAMs	I-131	1/97	5.5	5.5	5.5		<0.01
	I-133	9/97	25	4.7	8.3	2.1	<0.01
	I-135	5/97	71	28	50	8.8	0.011
	Pb-212	3/97	150	22	67	44	<0.01
	H-3	13/13	64000	4500	19000	4900	0.019
	Cm-244	2/4	0.030	0.021	0.025	0.0048	0.064
	Cs-137	2/4	0.090	0.029	0.060	0.030	<0.01
	Pu-239	1/4	0.0028	0.0028	0.0028	(a)	0.014
	Th-228	4/4	0.041	0.011	0.030	0.0067	0.074
	Th-230	4/4	0.053	0.036	0.042	0.0037	0.11
	Th-232	4/4	0.043	0.019	0.027	0.0054	0.39
	Total Sr	1/4	0.070	0.070	0.070	(a)	<0.01
	U-234	4/4	0.044	0.022	0.033	0.0053	0.037
	U-235	2/4	0.0060	0.0048	0.0054	0.00062	<0.01
	U-238	4/4	0.021	0.015	0.018	0.0014	0.018
ORR PAMs	H-3	27/31	650000	2400	51000	24000	0.051
	Cm-244	1/8	0.050	0.050	0.050	(a)	0.13
	Co-60	4/8	0.15	0.062	0.10	0.018	<0.01
	Pu-238	1/8	0.0040	0.0040	0.0040	(a)	0.013
	Th-228	7/8	0.016	0.0050	0.0089	0.0014	0.022
	Th-230	8/8	0.023	0.011	0.017	0.0016	0.042
	Th-232	8/8	0.011	0.0052	0.0072	0.00066	0.10
	Total Sr	1/8	0.072	0.072	0.072	(a)	<0.01
	U-234	8/8	0.21	0.0050	0.063	0.025	0.07
	U-235	5/8	0.052	0.0047	0.016	0.0091	0.016
RAMs	U-238	8/8	0.032	0.0094	0.017	0.0026	0.017
	H-3	4/6	190000	4400	53000	47000	0.053
	Cs-137	1/2	0.048	0.048	0.048	(a)	<0.01
	Pu-238	1/2	0.0044	0.0044	0.0044	(a)	0.015
	Th-228	1/2	0.0084	0.0084	0.0084	(a)	0.021
	Th-230	2/2	0.021	0.010	0.015	0.0054	0.038
	Th-232	2/2	0.0047	0.0029	0.0038	0.00093	0.055
	Total Sr	1/2	0.10	0.10	0.10	(a)	<0.01
	U-234	2/2	0.034	0.027	0.030	0.0036	0.034
	U-235	2/2	0.0050	0.0029	0.0040	0.0011	<0.01
	U-238	2/2	0.011	0.0074	0.0092	0.0018	<0.01
Note: DCG = Derived Concentration Guidelines ORR = Oak Ridge Reservation ORNL = Oak Ridge National Laboratory RAM = regional air monitor PAM = perimeter air monitor (a) Detected in only one sample; standard error not calculated.							

the year, with the highest rainfall in the winter months and July. Five-year cycles of wet and dry seasons are also evident. Precipitation is lost through evaporation, vegetation uptake, runoff to streams, and to groundwater recharge through the soil.

The Clinch River supplies most of the water to the Oak Ridge Reservation, the city of Oak Ridge, and other cities along the river (MMES 1994). Major surface water uses in the Oak Ridge area include withdrawals for industrial and public water supplies, commercial and recreational navigation, and other recreational activities, such as fishing, boating, and swimming.

4.3.8.2 Groundwater

Groundwater beneath the Oak Ridge Reservation is heavily influenced by the site geologic structure (Solomon et al. 1992). Geologic units of the Oak Ridge Reservation are assigned to two broad hydrologic groups: 1) the Knox aquifer in which flow is dominated by solution conduits in limestone that stores and transmits relatively large volumes of water, and 2) the Oak Ridge Reservation aquitards that are made up of sandstones, siltstones, and shales in which flow is controlled by fractures. Aquitards may store fairly large volumes of water, but they transmit only limited amounts (DOE 1995b). For more details on groundwater, refer to Solomon et al. (1992) and DOE (1993b).

4.3.9 Ecological Resources

4.3.9.1 Terrestrial Resources

Because of the greater continuity of forests and a lack of human disturbance over much of the Oak Ridge Reservation, wildlife species that are affected by forest fragmentation offsite may find an abundance of suitable habitat on the Oak Ridge Reservation. Thus, the Oak Ridge Reservation may serve as a refuge for wildlife and a source of wildlife migration (ORNL 1988).

The vegetation of the Oak Ridge Reservation has been categorized into seven plant communities that are characteristic of the intermountain regions of central and southern Appalachia (Figure 4-20) (Parr and Pounds 1987). The pine and pine-hardwood forest is one of the most extensive plant communities on the Oak Ridge Reservation. Important species of this community type include loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus echinata*), and Virginia pine (*Pinus virginiana*) (Parr and Pounds 1987). Another abundant plant community is the oak-hickory forest, which is commonly found on ridges throughout the Oak Ridge Reservation. For more information on vegetation, refer to ORNL (1988), Parr and Evans (1992), Pounds et al. (1993), and Cunningham and Pounds (1991).

Animals commonly found on the Oak Ridge Reservation include the American toad (*Bufo americanus*), eastern garter snake (*Thamnophis sirtalis*), Carolina chickadee (*Parus carolinensis*), northern cardinal (*Cardinalis cardinalis*), white-footed mouse (*Peromyscus leucopus*), and raccoon (*Procyon lotor*). Raptors, such as the red-shouldered hawk (*Buteo lineatus*) and great horned owl (*Bubo virginianus*), and

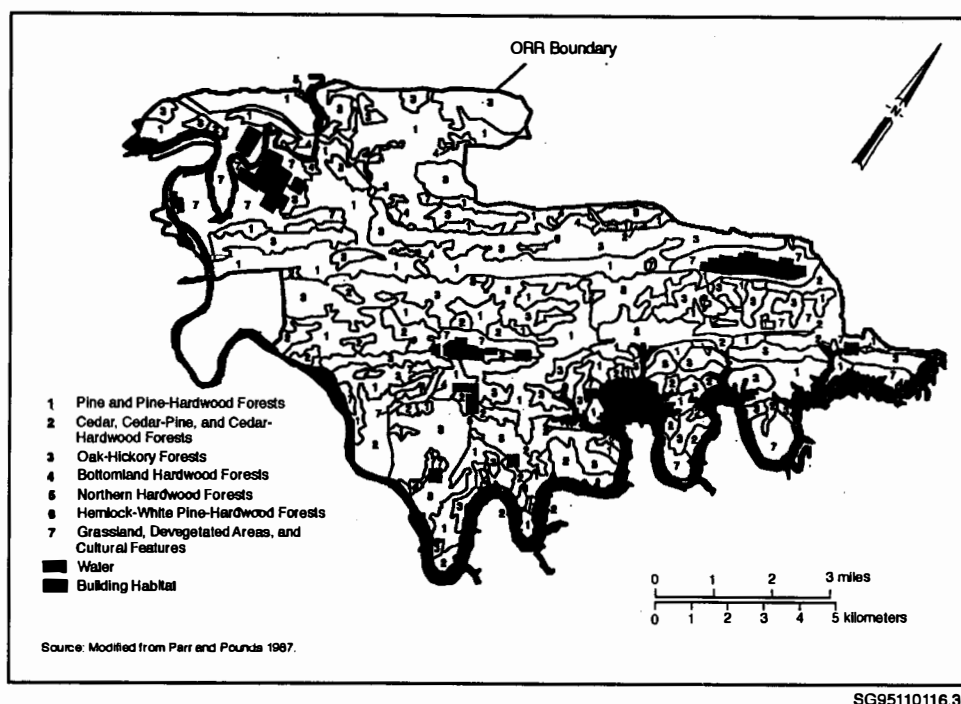


Figure 4-20. Plant Communities on the Oak Ridge Reservation

carnivores, such as the gray fox (*Urocyon cinereoargenteus*) and mink (*Mustela vison*), are ecologically important groups on the Oak Ridge Reservation (Loar et al. 1981).

4.3.9.2 Aquatic Resources

Aquatic habitats on or adjacent to the Oak Ridge Reservation range from small, free-flowing streams in undisturbed watersheds to larger streams with altered flow patterns because of dam construction. These aquatic habitats include tailwaters, impoundments, reservoir embayments, and large and small perennial streams. Further information can be found in DOE (1995I) and Loar (1994).

4.3.9.3 Wetlands

Wetlands on the Oak Ridge Reservation have recently been evaluated based on National Wetland Inventory maps and field surveys of vegetation (Cunningham and Pounds 1991). Soils and hydrology were not specifically considered in this survey. Wetlands on the Oak Ridge Reservation include emergent, scrub/shrub, and forested wetland located in embayments of the Melton Hill and Watts Bar reservoirs that border the Oak Ridge Reservation; along all the major streams, including East Fork Poplar Creek, Poplar Creek, Bear Creek, and their tributaries; in old farm ponds; and around groundwater seeps. For further detail, refer to Cunningham and Pounds (1991) and DOE (1995I).

4.3.9.4 Threatened and Endangered Species

Federal- and state-listed threatened, endangered, or other special-status species designated by the Endangered Species Act or the state's Nongame and Endangered Species and the Rare Plant Protection and Conservation Laws that have a reasonable potential for occurrence on the Oak Ridge Reservation are listed in Table 4-15. The table indicates that 25 of these species have recent records of occurrence on the Oak Ridge Reservation. The potential occurrence of the other 22 species listed is due to historical record, proximity to geographic ranges, and migratory nature of species. No animal species listed as threatened or endangered by the federal government are known to reside on the Oak Ridge Reservation (Kroodsma 1987); however, the bald eagle (*Haliaeetus leucocephalus*, federal, endangered) is a winter visitor to Watts Bar Lake and Melton Hill Lake. No critical habitat for threatened and endangered species, as defined in the Endangered Species Act (DOI 1992), exists on the Oak Ridge Reservation.

Rare and endangered plants include the purple fringeless orchid (*Platanthera peramoena*), which occurs in a natural area in Oak Ridge Reservation (Pounds et al. 1993) and pink lady's-slippers (*Cypripedium acaule*), which is expected to occur throughout the Pine Ridge area. Preferred habitat at some sites indicates a greater potential for occurrence of the barn owl (*Tyto alba*), black vulture (*Coragyps atratus*), Cooper's hawk (*Accipiter cooperii*), red-shouldered hawk, and sharp-shinned hawk (*Accipiter striatus*). Surveys of these sites would be required to verify the presence of these and other plant and animal species.

Although not all of the Oak Ridge Reservation has been surveyed for rare species, 33 different areas harboring rare plant species (federal or state listed) have been designated by DOE as National Environmental Research Park Natural Areas (Pounds et al. 1993). The plant species listed in Table 4-15 are scattered among these natural areas, but are not excluded from other areas on the Oak Ridge Reservation. These natural areas are designated to provide protection for rare plant and animal species. The designated areas include river and creek bluffs, calcareous (chalky) barrens, mesic forests, flood plains, and wetland cover classes.

4.3.10 Noise

The Oak Ridge Research Reactor is located approximately 4 km (2.5 mi) from the closest boundary of the Oak Ridge Reservation in a rural area with a higher level of public dispersed housing adjacent to the site. In rural areas and at residences removed from the influence of traffic, noise levels ranged from 35 to 50 dB(A) (DOE 19951). Suburban areas near the site typically have sound levels in the range of 53 to 62 dB(A).

4.3.11 Transportation

The information in the following section was taken from Volume 1, Appendix F, of DOE (19951).

Table 4-15. Federal- and State-Listed Threatened, Endangered, and Other Special-Status Species That Potentially Occur on or in the Vicinity of the Oak Ridge Reservation^(a)

Common Name	Scientific Name	Status ^(b)	
		Federal	State
Plants			
Appalachian bugbane ^(c)	<i>Cimicifuga rubifolia</i>	C2	T
Butternut	<i>Juglans cinerea</i>	C2	T
Canada (wild yellow) lily ^(c)	<i>Lilium canadense</i>	NL	T
Carey's saxifrage ^(c)	<i>Saxifraga careyana</i>	NL	S
Fen orchid ^(c)	<i>Liparis loeselii</i>	NL	E
Ginseng ^(c)	<i>Panax quinquefolius</i>	NL	T
Golden seal ^(c)	<i>Hydrastis canadensis</i>	NL	T
Gravid sedge ^(c)	<i>Carex gravida</i>	NL	S
Lesser lady's tresses ^(c)	<i>Spiranthes ovalis</i>	NL	S
Michigan lily	<i>Lilium michiganense</i>	NL	T
Mountain witch alder ^(c)	<i>Fothergilla major</i>	NL	T
Northern bush honeysuckle ^(c)	<i>Diervilla lonicera</i>	NL	T
Nuttall waterweed ^(c)	<i>Elodea nuttallii</i>	NL	S
Pink lady's-slipper ^(c)	<i>Cypripedium acaule</i>	NL	E
Purple fringeless orchid ^(c)	<i>Platanthera peramoena</i>	NL	T
Spreading false foxglove ^(c)	<i>Aureolaria patula</i>	C1	T
Tall larkspur ^(c)	<i>Delphinium exaltatum</i>	C2	E
Tubercled rein-orchid ^(c)	<i>Platanthera flava</i> var. <i>herbiola</i>	NL	T
Virginia spiraea	<i>Spiraea virginiana</i>	T	E
Fish			
Flame chub	<i>Hemitremia flammea</i>	NL	D
Tennessee dace ^(c)	<i>Phoxinus tennesseensis</i>	NL	D
Amphibians			
Green salamander	<i>Aneides aeneus</i>	NL	D
Hellbender ^(c)	<i>Cryptobranchus alleganiensis</i>	C2	D
Tennessee cave salamander ^(d)	<i>Gyrinophilus pallescens</i>	C2	T
Reptiles			
Cumberland turtle	<i>Chrysemys scripta troosti</i>	NL	D
Eastern slender glass lizard	<i>Ophisaurus attenuatus longicaudus</i>	NL	D
Northern pine snake	<i>Pituophis melanoleucus</i>	C2	T
Six-lined racerunner ^(d)	<i>Cnemidophorus sexlineatus</i>	NL	D

Table 4-15. (contd)

Common Name	Scientific Name	Status ^(b)	
		Federal	State
Birds			
Bachman's sparrow	<i>Aimophila aestivalis</i>	C2	E
Bald eagle ^(c)	<i>Haliaeetus leucocephalus</i>	E	E
Barn owl ^(c)	<i>Tyto alba</i>	NL	D
Bewick's wren	<i>Thyromanes bewickii altus</i>	C2	T
Black-crowned night heron ^(c)	<i>Nycticorax nycticorax</i>	NL	D
Black vulture ^(c)	<i>Coragyps atratus</i>	NL	D
Cooper's hawk ^(c)	<i>Accipiter cooperii</i>	NL	T
Grasshopper sparrow	<i>Ammodramus savannarum</i>	NL	T
Northern harrier	<i>Circus cyaneus</i>	NL	T
Osprey ^(c)	<i>Pandion haliaetus</i>	NL	E
Peregrine falcon	<i>Falco peregrinus</i>	E	E
Red-shouldered hawk ^(c)	<i>Buteo lineatus</i>	NL	D
Redheaded woodpecker	<i>Malanerpes erythrocephalus</i>	NL	D
Sharp-shinned hawk ^(c)	<i>Accipiter striatus</i>	NL	T
Mammals			
Eastern woodrat	<i>Neotoma floridana magister</i>	C2	D
Gray bat	<i>Myotis grisescens</i>	E	E
Indiana bat	<i>Myotis sodalis</i>	E	E
Smoky shrew	<i>Sorex fumeus</i>	NL	D
Southeastern shrew	<i>Sorex longirostris</i>	NL	D
(a) Sources: Barclay (1990, 1992); Bay (1991); Cunningham et al. (1993); Hardy (1991), Hardy et al. (1992); Kitchings and Story (1984); Kroodsma (1987); ORNL (1981); ORNL (1988); TDEC (1992a, 1992b, 1992c, 1992d); TWRC (1991); U.S. DOI (1990, 1991, 1992).			
(b) Status codes: C1 = Federal Candidate - Category 1 (probably appropriate to list) C2 = Federal Candidate - Category 2 (possibly appropriate to list, more study required) D = species deemed in need of management E = endangered NL = not listed S = species of special concern T = threatened, more study required.			
(c) Recent record of species occurrence on the Oak Ridge Reservation.			
(d) Species collected on the Oak Ridge Reservation in 1964 (ORNL 1988).			
(e) Observed near Oak Ridge Reservation on Melton Hill and Watts Bar lakes.			

4.3.11.1 Roadways

Regional and local transportation routes in the vicinity of the Oak Ridge Reservation are illustrated in Figures 4-21 and 4-17. Primary roads on the Oak Ridge Reservation include Tennessee state routes 95, 62, 162, 170 (Bethel Valley Road), and Bear Creek Road. All these roads are public highways, except Bear Creek Road. The remaining roads on the Oak Ridge Reservation are private.

4.3.11.2 Airports and Air Traffic

McGhee Tyson Airport in Knoxville, 64 km (40 mi) from the Oak Ridge Reservation, receives jet air passenger and cargo services from both national and international air carriers. The closest air transportation facility to Oak Ridge Reservation is Atomic Airport in Oliver Springs. Numerous other private airports are located in the region within 24 km (15 mi) of Oak Ridge Reservation.

4.3.12 Radiological Health and Safety

For general information applicable to the four alternative sites being considered, refer to Section 3.0.

Characterization of the radiological consequences of radionuclides released to the air from Oak Ridge Reservation operations during 1992 was accomplished by calculating, for each operating area and for the

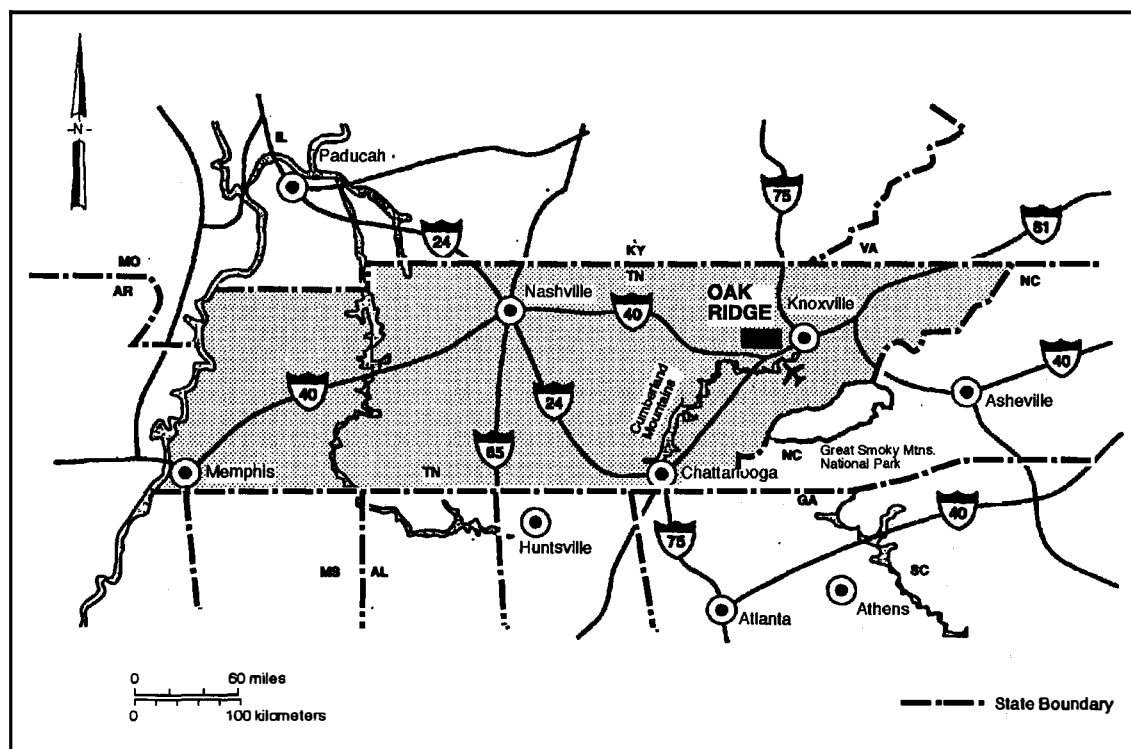


Figure 4-21. Highway System for the Oak Ridge Reservation

entire Oak Ridge Reservation, effective dose equivalents to the MEI and to the entire population residing within 80 km (50 mi) of the site. The dose calculations were made using the CAP-88 package of computer codes (Beres 1990), which contains the most recent approved version of the AIRDOS-EPA and DARTAB computer codes and the ALLRAD88 radionuclide data file (Kornegay et al. 1993). The calculated effective dose equivalents to the MEI from the Oak Ridge Reservation are listed in Table 4-16 and the collective effective dose equivalents to the public are shown in Table 4-17. The calculated effective dose equivalent to the MEI is below the 10-mrem National Emission Standards for Hazardous Air Pollutants standard and well below the 300 mrem the average individual receives from natural sources. The calculated collective effective dose equivalent to the population (43 person-rem) is 0.02% of the 264,000 person-rem the population could receive from natural sources of radiation. The expected latent cancer fatalities are much less than one (0.0172) for the population of 879,546 (Kornegay et al. 1993).

Table 4-16. Summary of Effective Dose Equivalents to the Maximally Exposed Individual from Oak Ridge Reservation Operations During 1992 (from Kornegay et al. 1993)

Operating Area	Total Effective Dose Equivalents (mrem)	
	Operating Area Max	Oak Ridge Reservation Max
Oak Ridge National Laboratory ^(a)	0.1	0.05
K-25 Site ^(b)	0.6	0.2
Y-12 Operating Area ^(c)	1.2	1.2
Entire Oak Ridge Reservation ^(d)	NA	1.4
(a) The MEI is located 4970 m (3.1 mi) SW of the 3039 stack and 5160 m (3.2 mi) WSW of the 7911 stack. (b) The MEI is located 5180 m (3.2 mi) WSW of the K-1435 stack. (c) The MEI is located 1080 m (0.7 mi) NNE of the Y-12 Operating Area release point. (d) The MEI for the entire Oak Ridge Reservation is the same as the Y-12 Operating Area MEI.		

Table 4-17. Summary of Collective Effective Dose Equivalents to the Public from Oak Ridge Reservation Operations During 1992 (from Kornegay et al. 1993)

Operating Area	Effective Dose Equivalents (person-rem) ^(a)
Oak Ridge National Laboratory	3
K-25 Site	29
Y-12 Operating Area	11
Oak Ridge Reservation	43
(a) The collective effective dose equivalents to the 879,546 persons residing within 80 km (50 mi) of the Oak Ridge Reservation.	

External gamma radiation measurements were made at 5 of 10 ambient air monitoring stations at the ORNL and reservation perimeter. The average value was 7.6 $\mu\text{R/h}$, and the values ranged from 11 to 4 $\mu\text{R/h}$. The standard deviation of the mean was 0.13 $\mu\text{R/h}$ (Kornegay et al. 1993). Typical values for cities in the contiguous United States usually range from 5 to 20 $\mu\text{R/h}$. The median exposure rate identified by the U.S. Environmental Protection Agency for U.S. cities during 1989 was 9.3 $\mu\text{R/h}$ (Eastern Environmental Radiation Facility 1989).

The total annual baseline worker dose from normal Oak Ridge Reservation operations is about 48 person-rem (DOE 1995). The latent cancer fatalities expected for this occupational dose is less than 1 (0.024).

4.3.13 Site Services

Electrical power is procured from the Tennessee Valley Authority. Several 161-kV overhead radial feeders are located on the site to supply power to the reactors and other plants on the site. See Table 4-18.

The source of water for some onsite reactors is Clinch River water impounded by the Melton Hill Dam. A filtration plant, with its 26,495,000-L (7-million-gal) storage reservoir, is a source of treated water on the site. The treated water supplies the fire protection system, process operations, sanitary requirements, and boiler feed at the steam plant. Heating and process steam is supplied by the main steam plant that houses four boilers.

Chemical needs include industrial gases (argon, helium, hydrogen, nitrogen, and oxygen) delivered in an aboveground distribution system. For current consumption, see Table 4-19.

Table 4-18. Existing Oak Ridge Reservation Utility Resource Requirements

Utility Resources	Average Daily Consumption	Peak Demand	System Capacity
Electricity	1320 MWh	70 MW	300 MW
Water	7,000,000 gal	5000 gpm	17,000 gpm
Conversion: To convert gallons (gal) to liters (L), multiply by 3.785.			

4.3.14 Waste and Spent Nuclear Fuel Management

Within the Oak Ridge Reservation are three primary complexes: the Y-12 Operating Area (a manufacturing and developmental engineering plant), the K-25 site (formerly the Oak Ridge Gaseous Diffusion Plant), and the ORNL. These facilities are used for research, development, and production. This section summarizes the management of waste products from these three primary complexes.

Table 4-19. Existing Oak Ridge Reservation Chemical Resource Requirements

Chemical Resources	Total Annual Consumption	Storage Capacity
Nitrogen	4,027,770,000 gal	46,083,000 gal
Argon	90,000,000 ft ³	3,430,000 ft ³
Helium	4,464,000 ft ³	707,000 ft ³
Hydrogen	5,464,000 ft ³	76,000 ft ³
Oxygen	44,886,000 gal	533,000 gal
Conversion: To convert gallons (gal) to liters (L), multiply by 3.785. To convert cubic feet (ft ³) to cubic meters (m ³), multiply by 0.028317.		

Ongoing nuclear-related activities at Oak Ridge Reservation have resulted in the generation of spent nuclear fuel, transuranic, low-level, mixed low-level, hazardous, and industrial solid waste categories. Facilities at the Y-12 Operating Area are used to manage low-level radioactive, hazardous (Resource Conservation and Recovery Act hazardous/mixed polychlorinated biphenyl and polychlorinated biphenyl/uranium), and nonhazardous solid wastes. Facilities at the K-25 site are used to manage low-level radioactive, hazardous, and mixed wastes. Nonhazardous solid wastes are disposed of at the Y-12 sanitary landfill. Facilities at the ORNL are used to manage transuranic, low-level radioactive, hazardous, and mixed waste.

Note that 1995 waste generation rates presented in this section are a representation of the annual generation rates for operations until the year 2035. The total amount of waste generated and disposed of at Oak Ridge has been reduced and continues to be reduced through waste minimization activities. The information presented in this section is directly from the SNF PEIS (DOE 1995I), unless otherwise noted.

4.3.14.1 Spent Nuclear Fuel

The Oak Ridge Reservation currently maintains spent nuclear fuel in various storage facilities, several shut down reactors, and one operating research reactor (the High Flux Isotope Reactor). The quantity of spent nuclear fuel at the Oak Ridge Reservation in 1995 was estimated as 650 kg (heavy metal) (DOE 1995b).

4.3.14.2 Low-Level Radioactive Waste

The Y-12 Operating Area, K-25 site, and the ORNL generate and manage low-level wastes. The total cumulative volume of low-level waste disposed of through 1993 was 441,700 m³ (577,482 yd³) (DOE 1994b).

4.3.14.3 Low-Level Mixed Waste

All three complexes at the Oak Ridge Reservation generate and manage mixed low-level wastes. They manage non-Resource Conservation and Recovery Act wastes (polychlorinated biphenyls, beryllium, and asbestos) contaminated by low-level radioactive materials as dangerous substances and include them with the Resources Conservation and Recovery Act-regulated radionuclide-contaminated materials as mixed wastes. The cumulative volumes of low-level mixed waste are as follows:

ORNL	4082.6 m ³ (5339.8 yd ³)
Y-12 Operating Area	12,043.1 m ³ (15,751.8 yd ³)
K-25 Site	30,572.9 m ³ (39,987.9 yd ³).

4.4 Idaho Falls Environment

4.4.1 Overview

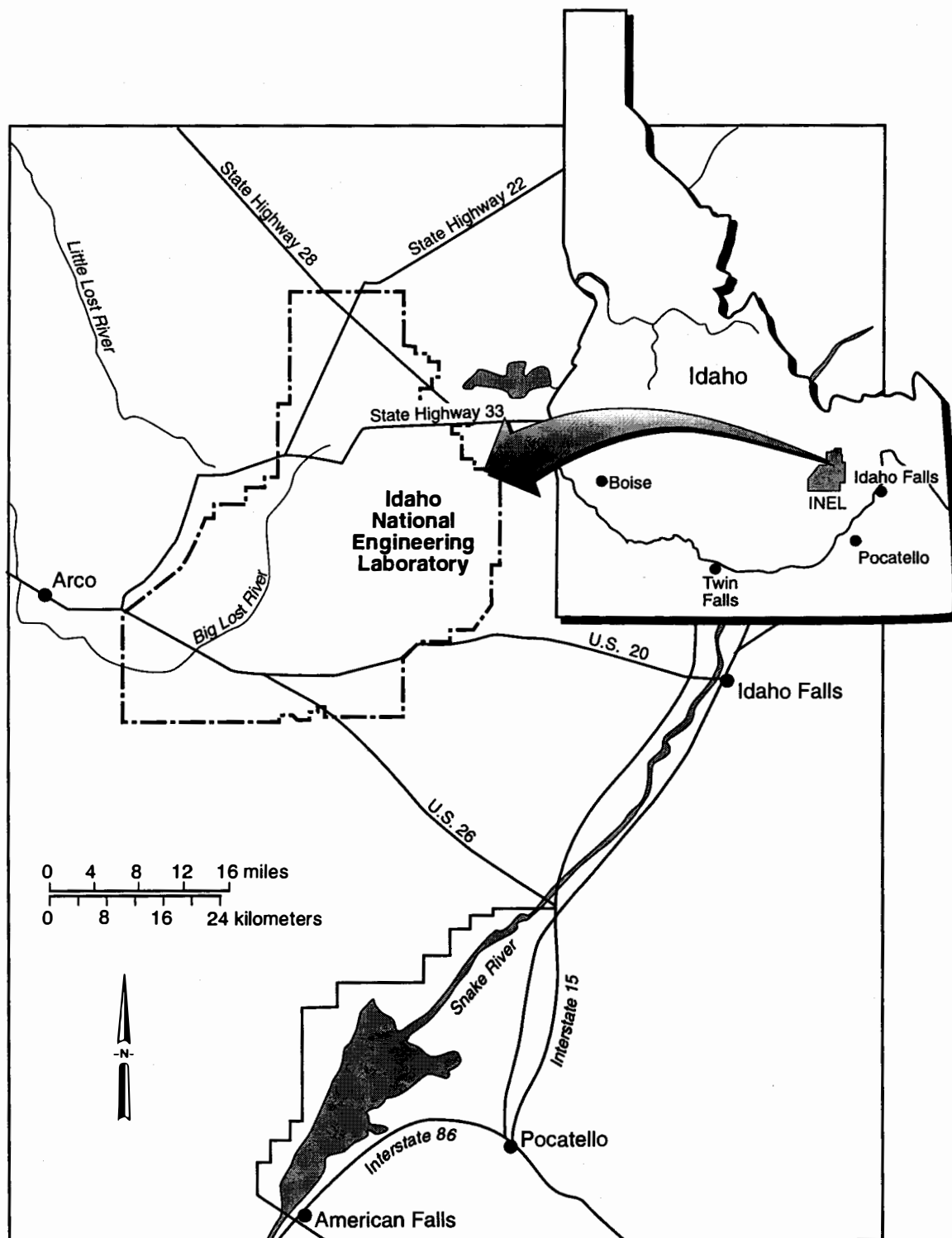
The Idaho National Engineering Laboratory (INEL) is located in southeastern Idaho, about 44 km (27 mi) west of Idaho Falls (Figure 4-22). The northern and western borders of the INEL site are roughly formed by the Bitterroot, Lemhi, and Lost River mountain ranges

The INEL site encompasses 2312 km² (893 mi²) in Butte, Bingham, Jefferson, Bonneville, and Clark counties, Idaho. About 145 km (90 mi) of paved public highways run through the INEL site, including U.S. highways 20 and 26, and state routes 22, 28, and 33. Other transportation routes include Interstate 15 and U.S. highways 93A and 191.

The Power Burst Facility is located in the southern portion of INEL, adjacent to the Waste Experimental Reduction Facility, and within 8 km (5 mi) of three other INEL facilities: the Auxiliary Reactor Area, the Idaho Chemical Processing Plant, and the Central Facilities Area. The Power Burst Facility is approximately 5 km (3 mi) northeast of the intersection of U.S. highways 20 and 26.

No known Native American traditional properties would be impacted by use and upgrading of the Power Burst Facility. Construction of the Power Burst Facility began in 1965 and was completed by 1972. The facility itself has not been recorded as a historic facility, and has not been formally evaluated for eligibility to the National Register of Historic Places.

The INEL is in seismic Zone 2B, where destructive earthquakes may occur. However, based on the historical record, the Eastern Snake River Plain has been seismically quiet. In October 1983, a Richter magnitude 7.3 earthquake known as the Borah Peak earthquake occurred along the central portion of the Lost River fault 24 km (15 mi) northwest of Mackay, Idaho. The Power Burst Facility is located approximately 113 km (70 mi) from the epicenter of that earthquake.



SG95110116.13

Figure 4-22. Location of Idaho National Engineering Laboratory

Radioactive emissions from INEL facilities include noble gases (argon, krypton, and xenon) and iodine; particulate fission products such as rubidium, strontium, and cesium; radionuclides formed by neutron activation, such as tritium, carbon-14, and cobalt-60; and very small quantities of heavy elements, such as uranium, thorium, plutonium, and their decay products.

Spent nuclear fuel currently is received from, and is expected to continue being received from, the Naval nuclear program and the Advanced Test Reactor at INEL. Spent nuclear fuel is stored in water-filled, fuel storage basins at various facilities throughout INEL. Some dry storage is also available. The total mass of spent nuclear fuel at INEL is estimated to be >458 tons.

As of 1993, INEL had approximately 147,000 m³ (192,189 yd³) of low-level waste with a projected 1995 annual generation volume of 4270 m³ (5583 yd³).

At present, DOE accepts only mixed low-level waste generated at the INEL for treatment and disposal at the INEL. DOE stores mixed low-level waste generated at the INEL at interim storage facilities until treatment systems become available or operational. A total of 1800 m³ (2400 yd³) of mixed low-level waste interim storage capacity is available at the INEL.

4.4.2 Land Use

4.4.2.1 Regional Area

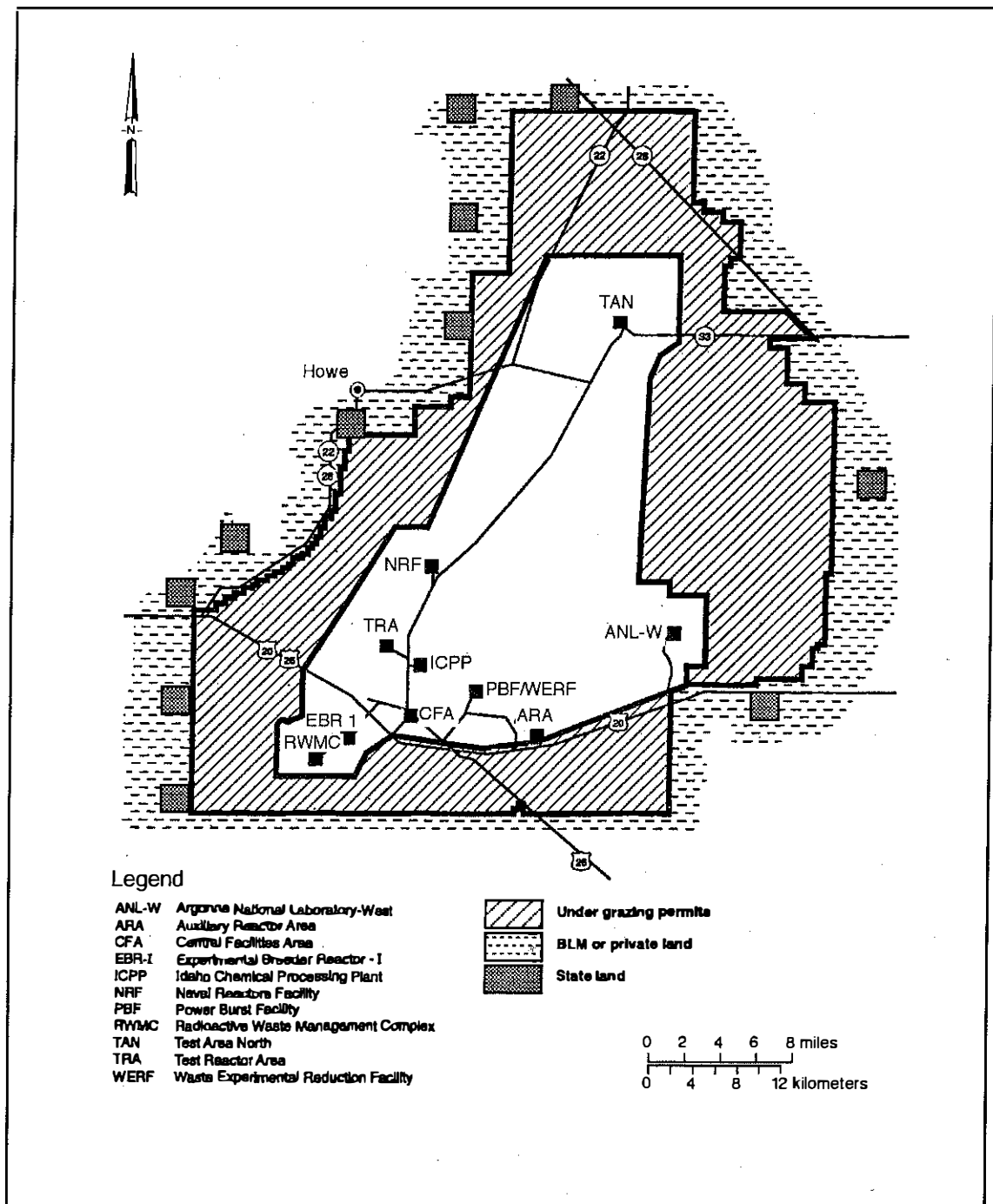
The INEL is located in southeastern Idaho with Mud Lake to the east; Arco, Butte City, and Howe to the west; and Atomic City to the south. The larger communities of Idaho Falls, Rexburg, Blackfoot, Pocatello, and Chubbuck are to the east and southeast of the INEL site. The Fort Hall Indian Reservation is to the southeast of the INEL. The Bitterroot, Lemhi, and Lost River mountain ranges border the INEL site on the north and west (DOE 1995o).

4.4.2.2 Idaho National Engineering Laboratory

The INEL site encompasses 2310 km² (893 mi²) in Butte, Bingham, Jefferson, Bonneville, and Clark counties in Idaho.

Categories of land use at the INEL include facility operations, grazing, general open space, and infrastructure, such as roads. Most (98%) of the INEL is open space. Some of this open space serves as a buffer zone between INEL facilities and other land uses. The U.S. Department of the Interior's Bureau of Land Management (BLM) grants and administers rights-of-way and grazing permits for the INEL.

Figure 4-23 shows selected land uses at the INEL and in the surrounding region (DOE 1995o).



SG95110116.1

Figure 4-23. Selected Land Uses for the Idaho National Engineering Laboratory Region

The INEL site is within the Medicine Lodge Resource Area (approximately 569 km²/220 mi²) in the eastern and southern portions of the INEL site and the Big Butte Resource Area (approximately 1743 km² or 673 mi²) in the central and western portions; the Bureau of Land Management administers both of these areas.

4.4.2.3 Power Burst Facility

The Power Burst Facility is located in the southern portion of INEL, adjacent to the Waste Experimental Reduction Facility, and within 8 km (5 mi) of three other INEL facilities: the Auxiliary Reactor Area, the Idaho Chemical Processing Plant, and the Central Facilities Area. The Power Burst Facility is approximately 5 km (3 mi) northeast of the intersection of U.S. highways 20 and 26 (Figure 4-23).

4.4.3 Socioeconomic Environment

Approximately 97% of the INEL workforce lived in a 7-county area of southeastern Idaho in 1991 (DOE 1995o). This area, referred to as the region of influence, includes the counties of Bingham, Bonneville, Butte, Clark, Jefferson, Bannock, and Madison (see Figure 4-24). The region also includes the Fort Hall Indian Reservation and Trust Lands (home of the Shoshone-Bannock Tribes) in Bannock, Bingham, Caribou, and Power Counties.

4.4.3.1 Demographic Characteristics

The predominant population in the region of influence is white non-Hispanic, 94.8% of the total (DOC 1994b). Total minority percentage for the region of influence (excludes white non-Hispanic) is 8.5%, compared to a minority population of 7.8% for Idaho State and of 24.2% for the U.S. In the region, Native Americans make up 2.2% of the population, persons classified as *other* make up 3.0% of the population, and persons classified as black or Asian make up less than 1% each. About 5.2% of the population is Hispanic.

Approximately 55.7% of the total population in the region of influence is between the ages of 18 and 65, slightly less than Idaho as a whole, where 57.4% of the population is between 18 and 65. Of the population age 25 and over, 82.3% has received a high school degree (ranging from 74.7% to 87.6% by county) and 19.0% has received a baccalaureate degree (ranging from 11.8% to 23.2% by county). For comparison, 79.7% of the population in Idaho has received a high school degree and 17.7% has received a baccalaureate degree (DOC 1994b).

The 1989, median household income level for the region ranged from \$23,000 to \$30,462 and the per capita income level for the region was \$10,550 (ranging from \$7385 to \$12,123). For the state of Idaho, the median household income was \$25,257 and the per capita income was \$11,457. At the time of the 1990 census, estimates indicated that 14.4% of the residents in the region of influence fell below official poverty thresholds, compared to 13.3% for the residents in Idaho and 13.1% of the persons in the U.S. (DOC 1994b).

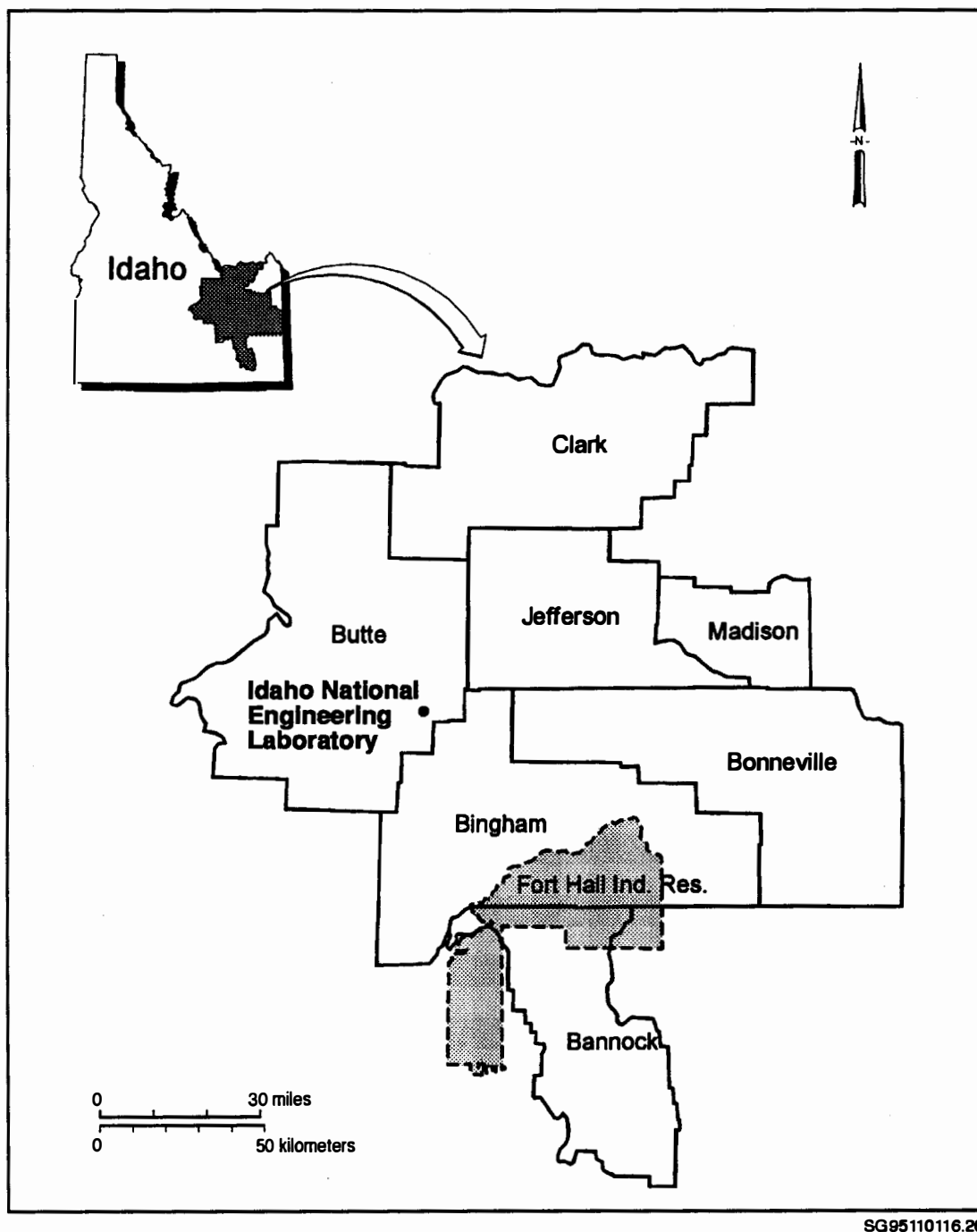


Figure 4-24. Region of Influence for Idaho National Engineering Laboratory

4.4.3.2 Economic Base

INEL plays a substantial role in the regional economy. During fiscal year 1992, INEL directly employed approximately 11,600 personnel (DOE 1995b), accounting for about 10% of total regional employment. The major employers at INEL are DOE-Idaho, DOE-Idaho contractors, Argonne National Laboratory-West, and the Naval Reactors Facility. Projections, as of January 1995, indicate the total number of jobs at INEL will decrease to approximately 8620 in fiscal year 1995 and to approximately 7250 in fiscal year 2004 (DOE 1995o). Projected decreases in INEL employment are primarily related to contractor consolidation, which accounts for 64% of the projected losses between fiscal year 1994 and fiscal year 2004, and to reduced activities at the Naval Reactors Facility, which accounts for 33% of the projected job losses (DOE 1995o).

Wages and salaries paid to INEL employees in fiscal year 1992 totaled nearly \$477 million. An additional \$113.9 million in procurements were made in the region. As employment decreases, total INEL payroll is expected to decrease from \$373 million in fiscal year 1995 to approximately \$314 million by fiscal year 2004 (DOE 1995j).

In 1992, INEL employees paid an estimated \$60 million in federal withholding tax and \$24 million in state withholding tax (DOE 1995o).

The average annual employment in the region of influence during calendar year 1993 was 115,872 workers, who earned a total of \$2.69 billion in wages (DOC 1994a) (see Table 4-20). At the

Table 4-20. 1993 Employment Profile in the Idaho National Engineering Laboratory
Region of Influence (in number of jobs)

Economic Sectors	Bannock	Bingham	Bonneville	Butte	Clark	Jefferson	Madison	Total
Agriculture	253	691	551	29	42	674	(D)	2,240
Mining	32	86	28	(D)	(D)	15	(D)	161
Construction	1,885	857	3,190	(D)	(L)	580	432	6,944
Manufacturing	2,395	2,706	2,318	1,541	(D)	808	1,221	10,989
Transportation and Public Utilities	2,409	460	1,243	20	12	162	236	4,542
Trade	9,061	3,965	12,384	250	69	1,179	2,829	29,737
Finance, Insurance, and Real Estate	2,323	575	2,339	52	12	224	437	5,962
Services	7,501	3,544	14,194	4,464	27	778	3,558	34,066
Government	7,921	3,108	5,482	1,439	148	1,119	1,478	20,695
Total	33,780	15,992	41,729	7,839	475	5,539	10,518	115,872
(D) Not shown to avoid disclosure of confidential information. (L) Less than 10 jobs. Estimates are included in totals. Source: DOC 1994b.								

sectoral level, employment and wages were highest in the service, government, and trade sectors of the regional economy. Together these sectors accounted for 73% of the employment and 68% of the wages in the regional economy.

4.4.4 Cultural Resources

The INEL site contains a rich and varied inventory of cultural resources. Previous archaeological surveys for the area of the Power Burst Facility indicated the area is archaeologically sensitive (Homer et al. 1987). However, none of these archaeological sites would be impacted by proposed modifications to the reactor. No known Native American traditional properties would be impacted by use and upgrading of the Power Burst Facility.

4.4.5 Aesthetic and Scenic Resources

Most of the INEL site consists of open undeveloped land, covered predominantly by large sagebrush and grasslands. Pasture and irrigated farmland border much of the INEL site. The Craters of the Moon National Monument is about 24 km (15 mi) southwest of the INEL site western boundary. The monument is located in a designated wilderness area, which must maintain Class I (very high) air quality standards or minimal degradation, as defined by the Clean Air Act (42 USC 7401, 40 CFR 50; 40 CFR 51). Under Section 169a of the Clean Air Act, air quality includes visibility and scenic view considerations (DOE 1995o).

The Craters of the Moon National Monument, Hell's Half Acre Wilderness Study Area, Black Canyon Wilderness Study Area, Camas National Wildlife Refuge, Market Lake State Wildlife Management Area, North Lake State Wildlife Management Area, Yellowstone National Park, Grand Teton National Park, Jackson Hole Recreation Complex, and Targhee and Challis National Forests are in the general vicinity of INEL.

Features of the natural landscape have special significance to the Shoshone-Bannock Tribes. The environment of the INEL site is within the visual range of Fort Hall Reservation (DOE 1995o).

4.4.6 Geologic Resources

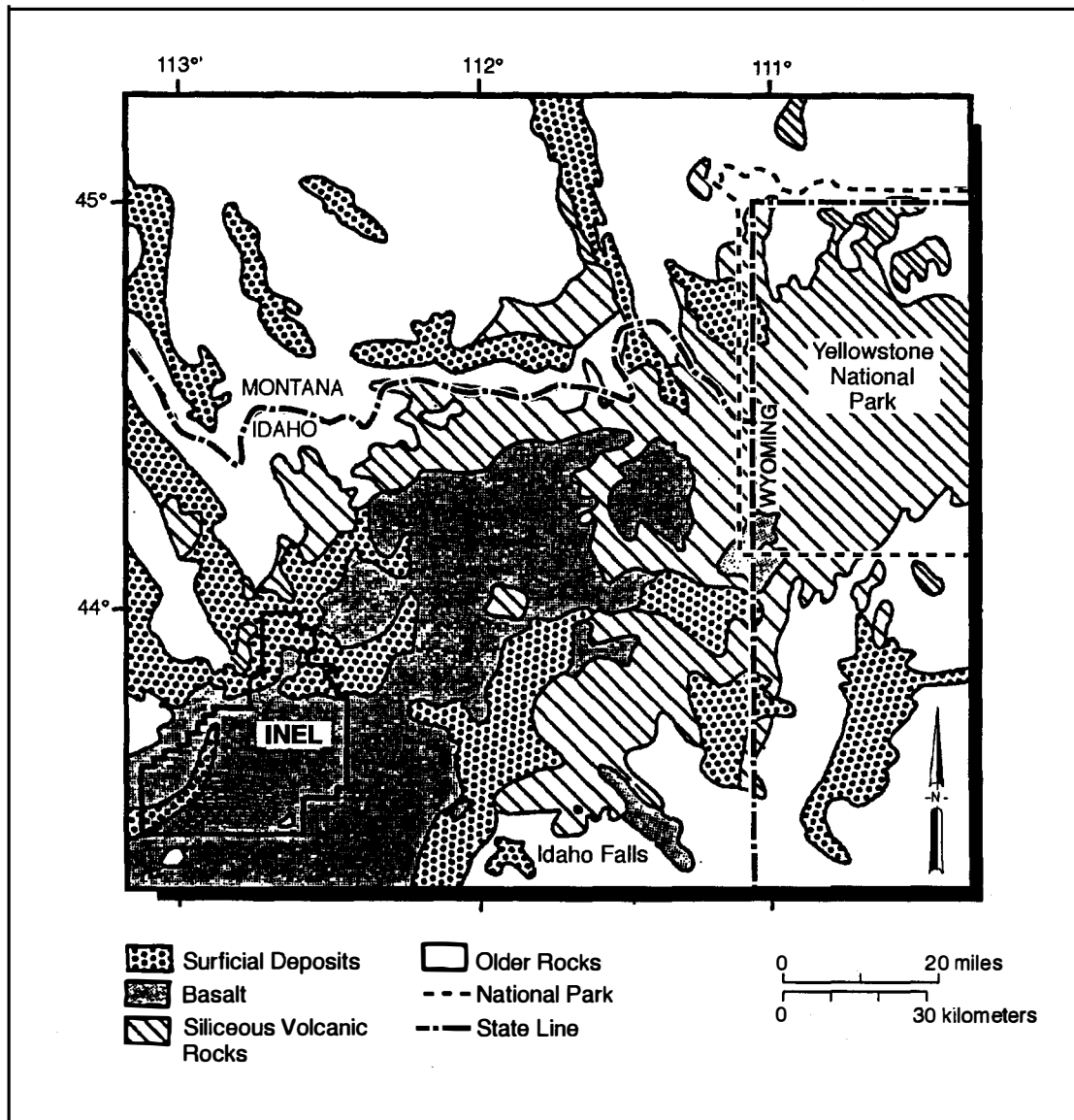
This section summarizes the physiography, geology, and seismic hazards at the INEL. A more detailed summary of these subjects can be found in DOE (1991b) with site-specific information in DOE (1993a).

4.4.6.1 General Geology

Physiography. The INEL is located on the western edge of the Eastern Snake River Plain, northwest of Idaho Falls (Figure 4-22). The INEL occupies 2300 km² (890 mi²) of remote desert in southern Idaho.

The Eastern Snake River Plain is bounded on the north and south by mountains and valleys of the Basin and Range Province and on the northeast by the Yellowstone Plateau (DOE 1995b). For further details, refer to DOE (1990) and LLNL (1990).

Geology. The Eastern Snake River Plain forms a broad northeast-trending, crescent-shaped trough consisting primarily of surface basaltic lava flows formed 1.2 million to 2100 years ago (DOE 1995b) (Figure 4-25). The topography of the INEL is flat and consists of basaltic lava flows interbedded with



SG95110116.30

Figure 4-25. Geology of the Eastern Snake River Plain

sedimentary strata. The sequence is underlain by an unknown thickness of rhyolitic and pyroclastic flow materials formed 1.2 to 3.0 Ma (Kuntz et al. 1990). Refer to Kuntz et al. (1990) for further detail.

Structure. Vents for basaltic volcanism are concentrated in volcanic rift zones and along the central axis of the Snake River Plain (Figure 4-26). The rift zones are northwest trending features 2 to 20 km (1.2 to 12.4 mi) wide and 20 to 95 km (12.4 to 59 mi) long, characterized by alignments of basaltic vents, fissures, normal faults, and grabens produced by shallow dike injection (Wong et al. 1992). Further information can be found in LANL (1990) and Hackett and Smith (1992).

Soils. Soils at the INEL include loam, clay, loess, and lacustrine sediments. Soil depth and water-holding capacity vary considerably around the INEL (DOE 1990). The U.S. Fish and Wildlife National Wetlands Inventory identified more than 130 areas inside the INEL with potential wetlands characteristics.

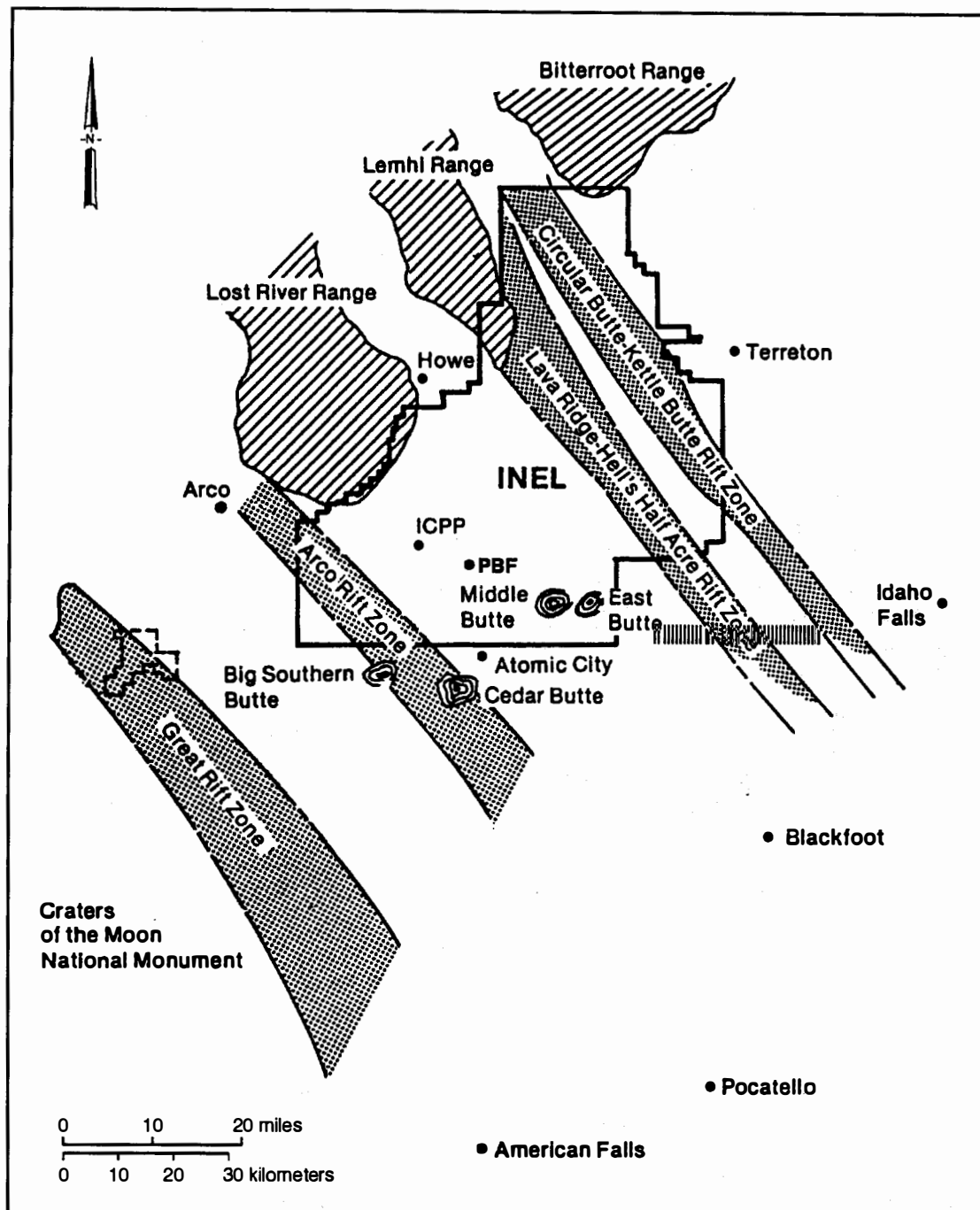
4.4.6.2 Mineral Resources

Southeastern Idaho State mineral resources include crushed basalt, clays for alumina, fluorspar, and vanadium-producing phosphate rock. Mineral resources at INEL include several quarries or pits that supply sand, gravel, pumice, silt, clay, and aggregate for road construction and maintenance, new facility construction and maintenance, waste burial activities, and ornamental landscaping cinders (DOE 1995b). These industrial minerals are of low unit value and are not considered exclusive to INEL.

4.4.6.3 Site Stability

The INEL is in seismic Zone 2B, which is defined by the Uniform Building Code as an area where destructive earthquakes may occur. Based on the historical record, the Eastern Snake River Plain has been seismically quiescent, while the surrounding Basin and Range Province has a fairly high rate of seismicity (Wong et al. 1992; DOE 1995b). Detailed earthquake monitoring by the INEL seismic network from 1972 to 1990 suggests the Eastern Snake River Plain is characterized by very infrequent and small-magnitude microearthquakes.

Potential seismic sources considered most significant to INEL, based on past and current studies, include the Basin and Range faults immediately north to northwest of the INEL, including the Lemhi fault; the Eastern Snake River Plain volcanic rift zone; the Eastern Snake River Plain Basin and Range boundary zone, and random earthquakes (Wong et al. 1992). Three major Basin and Range normal faults approach the northwest margin of the Eastern Snake River Plain adjacent to INEL: the Lost River fault, the Lemhi fault, and the Beaverhead fault (Figure 4-27). In October 1983, a Richter magnitude 7.3 earthquake known as the Borah Peak earthquake occurred along the central portion of the Lost River Fault 24 km (15 mi) northwest of Mackay, Idaho (Wong et al. 1992, DOE 1990). The Power Burst Facility is located approximately 113 km (70 mi) from the epicenter of that earthquake. No damage was reported in the vicinity.



SG95110116.31

Figure 4-26. Rift Zones and Volcanic Structures Near the Idaho National Engineering Laboratory (EG&G 1987)

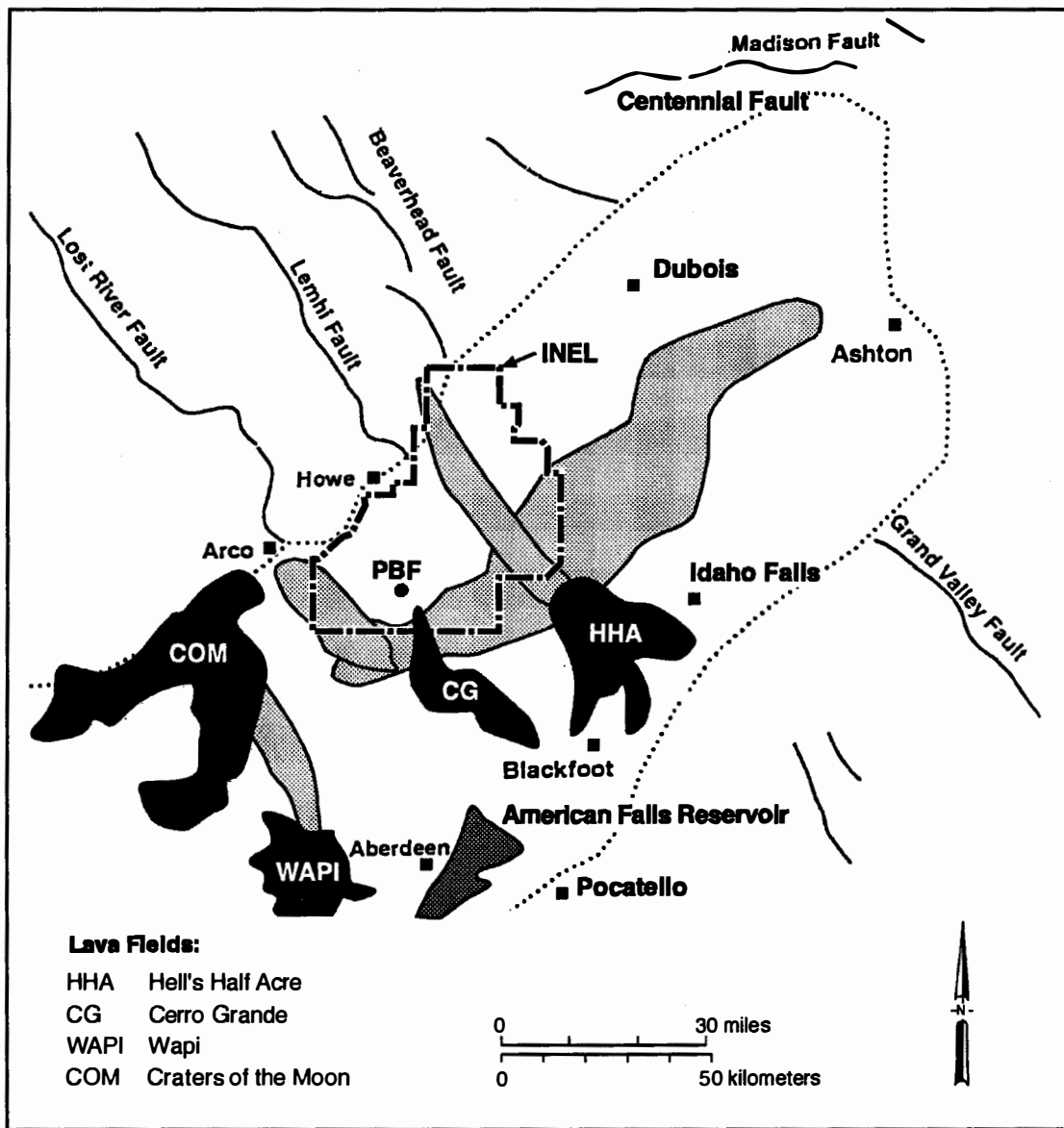


Figure 4-27. Major Volcanic and Tectonic Elements Near the Idaho National Engineering Laboratory

Three volcanic zones occur within the boundaries of the INEL: the Arco and Lava Ridge-Hell's Half Acre rift zones and the axial volcanic zone. Although no seismicity has been observed in the vicinity of these volcanic zones, the potential exists for seismicity associated with dike injection (Wong et al. 1992).

Despite the observation indicating the historical seismicity of an area may not reflect potential seismic hazards, the historical quiescence of the Eastern Snake River Plain probably is a reflection of low

differential stresses within this plain (Wong et al. 1992). In general, geologic evidence indicates the area has been relatively stable for a long period of time.

4.4.7 Air Quality

The INEL site is in the semiarid steppe region of the Eastern Snake River Plain (DOE 1987). A brief characterization of the climate is presented in Appendix D.

4.4.7.1 Nonradiological Air Quality

The INEL is in the Eastern Idaho Intrastate Air Quality Control Region. Atmospheric contaminant levels that result from operations at INEL or from nearby communities are low. In addition, atmospheric dispersion at INEL is not constrained by topography, and the site is well-ventilated. Nonradioactive airborne effluents originate from calcination of high-level radioactive liquid waste at the New Waste Calcining Facility, combustion of coal for steam generation at the Coal-Fired Steam-Generating Facility, combustion of fuel oil for heating at all INEL facilities, motor vehicle exhausts, and fugitive dusts from waste burial and construction activities (Rope et al. 1993). Neither INEL nor most of the surrounding counties are designated as nonattainment areas (40 CFR 81.313) for the National Ambient Air Quality Standards (40 CFR 50). The exceptions are portions of Bannock and Power counties, within about 80.5 km (50 mi) of INEL, which are designated as nonattainment areas for PM₁₀. Ambient air quality data monitored in the vicinity of INEL indicate the site is in compliance with applicable air quality standards (DOE 1991b).

4.4.7.2 Radiological Air Quality

The major source of radiation exposure in the Eastern Snake River Plain is from natural background radiation sources, such as cosmic rays; radioactivity naturally present in soil, rocks, and the human body; and airborne radionuclides of natural origin (such as radon). Sources of radioactivity related to INEL operations include research and training reactors, spent nuclear fuel testing and stabilization, irradiated material and fuel examination, nuclear waste treatment and storage, and depleted uranium armor production.

The DOE evaluates proposed new and modified sources of emissions at INEL to determine the net emissions increase of all pollutants. For radionuclides, major sources are defined as facilities where emissions would result in an offsite dose of 0.1 mrem per year or greater.

Radioactive emissions from INEL facilities include noble gases (argon, krypton, and xenon) and iodine; particulate fission products such as rubidium, strontium, and cesium; radionuclides formed by neutron activation such as tritium, carbon-14, and cobalt-60; and very small quantities of heavy elements such as uranium, thorium, plutonium, and their decay products. Table 4-21 summarizes radioactive emissions from the Power Burst Facility and the INEL site in 1991.

Table 4-21. Summary of Radioactive Emissions to the Atmosphere from the Power Burst Facility and the Idaho National Engineering Laboratory Site (total in curies) (DOE 1995o)

Facility	H-3/C-14	Mixed Fission and Activation Products	U/Th/Transuranics
Power Burst Facility/ Waste Experimental Reduction Facility	4.9×10^1	1.3×10^0	9.8×10^{-3}
Idaho National Engineering Laboratory Total	2.1×10^3	5.6×10^0	1.0×10^{-2}

Historically, the radionuclide with the highest emission rate was the noble gas krypton-85, which was released primarily by the chemical reprocessing of spent nuclear fuel at the Idaho Chemical Processing Plant (DOE 1995o). Reactor operations release noble gas isotopes with short half-lives, including argon-41 and isotopes of xenon. Other activities at the INEL, including waste management operations, result in very low levels of airborne radionuclide emissions. Radionuclide emissions from the INEL during 1994 included about 550 Ci of tritium, 2100 Ci of noble gases, less than 1 microcurie of transuranics, and about 10 Ci of other mixed fission and activation products. Emissions from the Power Burst Facility and surrounding area amounted to less than 1 microcurie of mixed fission products during that time (DOEq). Gross alpha and gross beta in air concentrations at perimeter and distant locations are similar to locations within the INEL boundary, (see Tables 4-22 and 4-23).

Table 4-22. Gross Alpha Activity in Air (1993) Around Idaho National Engineering Laboratory (taken from Mitchell 1994)

Group Location	Number of Samples	Range of Samples ($\times 10^{-12}$ Ci/m ³)	Annual Mean ($\times 10^{-12}$ Ci/m ³)
Distant	103	0.1 - 2.5	1.5 ± 0.1
Boundary	101	0.3 - 4.1	1.8 ± 0.2
INEL	164	0.2 - 4.4	1.6 ± 0.1

Table 4-23. Gross Beta Activity in Air (1993) Around Idaho National Engineering Laboratory (taken from Mitchell 1994)

Group Location	Number of Samples	Range of Samples ($\times 10^{-12}$ Ci/m ³)	Annual Mean ($\times 10^{-12}$ Ci/m ³)
Distant	198	7 - 87	25 $\pm$ 2
Boundary	356	8 - 104	26 $\pm$ 2
INEL	612	5 - 117	28 $\pm$ 1

Ambient air quality standards for Idaho are the same as the National Ambient Air Quality Standards, but include total suspended particulates and fluorides. The Idaho Department of Health and Welfare also has ambient concentration limits for hazardous and toxic air pollutants.

4.4.8 Water Quality

This section summarizes the surface water and groundwater resources at INEL. A more detailed summary can be found in DOE (1995b), with site-specific information in DOE (1990) and Holdren et al. (1994).

4.4.8.1 Surface Water

The INEL is in the Pioneer Basin, a closed drainage basin. Surface waters at the INEL consist of three intermittent streams, the Big Lost River, the Little Lost River, and Birch Creek. The drainages do not connect to the Snake River (the largest major river in the region). The Power Burst Facility is located approximately 5 km (3.5 mi) southeast of the Big Lost River channel. During episodes of high flow, surface water is presently diverted into a series of spreading areas (DOE 1990) and is not a threat to the Power Burst Facility. In 1984, the dikes were raised to enable the flood control system to contain floods with an average return period of 300 years. In most years, all surface waters in the Little Lost River and Birch Creek watersheds are diverted to irrigation before entering the site.

4.4.8.2 Groundwater

The regional Snake River Plain aquifer occurs at various depths across the site. In northern INEL the aquifer is about 60 m (200 ft) beneath the surface. At the southwestern boundary, groundwater is at a depth of approximately 180 m (600 ft) (Holdren et al. 1994). Groundwater recharge zones to the aquifer are to the north and northeast, with gradients in southerly and southwesterly directions. Flow rates range from less than 0.3 m (1 ft) per day to about 4 m (12 ft) per day. The aquifer near the Power Burst Facility is approximately 137 m (450 ft) below ground surface. Perched water has been found locally at depths ranging from 12 to 115 m (40 to 377 ft) (DOE 1990). These features are short-lived, resulting from

subsurface discharge of large volumes of process water. The perched water zones are highly localized and not of significance in contaminant transport (Holdren et al. 1994).

4.4.9 Ecological Resources

4.4.9.1 Terrestrial Resources

Vegetation on the INEL site is primarily of the shrub-steppe type and is a small fraction of the 450,000 km² (173,745 mi²) of this vegetation type in the Intermountain West. The 15 vegetation associations on the INEL site range from primarily shadscale-steppe vegetation at lower altitudes through sagebrush- and grass-dominated communities to juniper woodlands along the foothills of the nearby mountains and buttes (Rope et al. 1993; Kramber et al. 1992; Anderson 1991). These associations can be grouped into six basic types: juniper woodland, grassland, shrub-steppe (which consists of sagebrush-steppe and salt desert shrubs), lava, bareground-disturbed, and wetland vegetation. See Rope et al. (1993), Kramber et al. (1992), and Anderson (1991) for further information.

The INEL site supports animal communities characteristic of shrub-steppe vegetation and habitats. More than 270 vertebrate species occur, including 46 mammal, 204 bird, 10 reptile, 2 amphibian, and 9 fish species (Arthur et al. 1984; Reynolds et al. 1986). Common small-mammal genera include mice (*Reithrodontomys* spp. and *Peromyscus* spp.), chipmunks (*Tamias* spp.), jackrabbits (*Lepus* spp.), and cottontails (*Sylvilagus* spp.). See Arthur et al. (1984), Reynolds et al. (1986), and DOE (1995o) for further information.

4.4.9.2 Aquatic Resources

Of the three natural surface water drainages that enter INEL (Big Lost River, Little Lost River, and Birch Creek), only the Big Lost River is close to the proposed facility. The Big Lost River drains approximately 3755 km² (1450 mi²) of land before reaching the site. The river is dammed upstream from the site, and most water is diverted for irrigation. Water reaching the site disappears into the ground by natural infiltration basins, and no water flows off of the site.

Although general aquatic data are available in the INEL EIS (DOE 1995b), no data are available concerning the communities of algae or macroinvertebrates occurring in the Big Lost River near the proposed site. The lack of data is due, in part, to the absence of aquatic life in the Big Lost River during normal years. Fish, including kokanee salmon (*Oncorhynchus nerka*), rainbow trout (*Oncorhynchus mykiss*), and mountain whitefish (*Prosopium williamsoni*) occur on the INEL site only when the Big Lost River flows onto the site as a result of heavy rain or snowfall in the mountains to the northwest during years of exceptional runoff. These fish are not permanent residents (DOE 1995o).

4.4.9.3 Wetlands

The U.S. Fish and Wildlife Service National Wetlands Inventory has identified more than 130 areas inside INEL boundaries that might possess wetlands characteristics. Surveys conducted in the fall of 1992 indicate these possible wetlands cover about 1.4% (33 km²/12.8 mi²) of the INEL site (Hampton et al. 1993). Approximately 70% of these possible wetlands areas occur near the Big Lost River and its spreading areas and playas, near the Birch Creek Playa, and in an area north of and in the general vicinity of Argonne National Laboratory-West. These playas are approximately 4.8 to 6.4 km (3 to 4 mi) from the Test Area North and about 27.5 km (17 mi) from the Power Burst Facility. Limited riparian (riverbank) communities with mature trees along the Big Lost River reflect the intermittent flow in the river (1986 and 1993 were the last 2 years with flow reported on the site). The remainder of the possible wetlands are scattered throughout the INEL site. In 1994, INEL began evaluating these potential wetlands to determine if they meet the U.S. Army Corps of Engineers definition of jurisdictional wetlands (COE 1987). Approximately 20 wetlands are near facilities and are mostly man-made (such as, industrial waste and sewage treatment ponds, borrow pits, and gravel pits).

4.4.9.4 Threatened and Endangered Species

State and federal regulatory agency lists, the Idaho Department of Fish and Game Conservation Data Center list, and information from site surveys provided the information to identify federal- and state-protected, candidate, and sensitive species that potentially occur on the INEL. This information identified two federal endangered (bald eagle and peregrine falcon) and nine Federal Category 2 candidate species as animals that potentially occur on the INEL site (Table 4-24). Five animal species listed by the state as species of special concern occur on the site. See Chowlewa and Henderson (1984) for further information.

4.4.10 Noise

The Power Burst Facility is located about 13 km (8 mi) from the INEL site perimeter and from Atomic City. Ambient noise measurements are not available, but should be similar to background levels at Hanford, which range from 30 to 49 dB(A).

4.4.11 Transportation

Roads provide the primary access to and from the INEL site. Commercial shipments are transported via truck and plane; some bulk materials are transported via rail; waste is transported by road and rail. This section discusses the existing transportation infrastructure for the INEL site, including traffic volumes and transportation routes. The information in this section was taken from DOE (1995o).

4.4.11.1 Roadways

Figure 4-22 shows the existing regional highway system. Two interstate highways serve the regional area. Interstate 15 (I-15), a north-south route that connects several cities along the Snake River, is

Table 4-24. Threatened and Endangered Species, Special Species of Concern, and Sensitive Species That May Be Found on the Idaho National Engineering Laboratory

	Name	Status ^(a)	Comments
Birds	Northern goshawk (<i>Accipiter gentilis</i>) Burrowing owl (<i>Athene cunicularia</i>) Ferruginous hawk (<i>Buteo regalis</i>) Swainson's hawk (<i>Buteo swainsoni</i>) Great egret (<i>Casmerodius albus</i>) Merlin (<i>Falco columbarius</i>) Peregrine falcon (<i>Falco peregrinus</i>) Gyrfalcon (<i>Falco rusticolus</i>) Common loon (<i>Gavia immer</i>) Bald eagle (<i>Haliaeetus leucocephalus</i>) Long-billed curlew (<i>Numenius americanus</i>) American white pelican (<i>Pelecanus erythrorhynchos</i>) White-faced ibis (<i>Plegadis chihi</i>)	C2, SSC, FS, BLM C2, BLM C2, SSC, BLM BLM SSC SSC, BLM E BLM SSC, FS E SPS, BLM SSC C2	The ferruginous hawk nests on and migrates through the INEL. This species is found throughout the INEL, but is observed more frequently in juniper woodlands. The peregrine falcon has been observed rarely in winter, but has not been observed during other seasons. The last sighting was in 1993 (Morris 1993). It is not known to nest on the INEL and is not commonly observed near facilities. The bald eagle is a winter resident and is locally common in the far north end and on the western edge of the INEL near Howe. It is not known to nest on the INEL and is not commonly observed near facilities. The white-faced ibis, which uses aquatic and riparian habitats, is an uncommon migrant at the INEL. The long-billed curlew is known to nest on the north end of the INEL near agricultural lands. The northern goshawk is a casual migrant through the INEL.
Mammals	Merriam's shrew (<i>Sorex merriami</i>) Pygmy rabbit (<i>Brachylagus (Sylvilagus) idahoensis</i>) California myotis (<i>Myotis californicus</i>) Fringed myotis (<i>Myotis thysanodes</i>) Western pipistrelle (<i>Pipistrellus hesperus</i>) Townsend's western big-eared bat (<i>Plecotus townsendii</i>) Long-eared myotis (<i>Myotis evotis</i>) Small-footed myotis (<i>Myotis subulatus</i>)	SPS C2, BLM, SSC SSC SSC SSC, BLM C2, SSC, FS, BLM C2 CS	The pygmy rabbit is common on the INEL, but its distribution is patchy (Reynolds et al. 1986). Roosts and hibernation caves for Townsend's western big-eared bat occur on the INEL. All are over 7 km (3 mi) from facilities. Brood caves might exist on the site but have not been located.
Plants	Lemhi milkvetch (<i>Astragalus aquilonius</i>) Painted milkvetch (<i>Astragalus ceramicus</i> var. <i>apus</i>) Winged-seed evening primrose (<i>Camissonia pterosperma</i>) Nipple cactus (<i>Coryphantha missouriensis</i>) Spreading gilia (<i>Ipomopsis (Gilia) polycladon</i>) King's bladderpod (<i>Lesquerella kingii</i> var. <i>cobrensis</i>) Tree-like oxytheca (<i>Oxytheca dendroidea</i>) Sepal-tooth dodder (<i>Cuscuta denticulata</i>)	BLM, FS, INPS 3c, INPS-M BLM, INPS-S INPS-M BLM, INPS-2 INPS-M INPS-S INPS-I	The eight plant species identified as sensitive, rare, or unique that are known to occur on the INEL occur primarily at a distance from INEL facilities and are uncommon on the INEL because they require unique microhabitat conditions.
Insects	Idaho pointheaded grasshopper (<i>Acrolophitus pulchellus</i>)	C2, BLM	Occurs just north of the INEL.
(a) Key: C2 = Federal Category 2 species. INPS-S = Idaho Native Plant Society sensitive. FS = U.S. Forest Service monitored. E = Federal and state endangered species. INPS-I = Idaho Native Plant Society State Priority I. SPS = State protected species. BLM = Bureau of Land Management monitored. 3c = No longer considered for federal listing. INPS-M = Idaho Native Plant. INEL = Idaho National Engineering Laboratory. SSC = State species of special concern. INPS-2 = Idaho Native Plant Society State Priority 2.			

approximately 40 km (25 mi) east of the INEL site. Interstate 86 intersects I-15 approximately 64 km (40 mi) south of the INEL site, and provides a primary linkage from I-15 to points west. I-15 and U.S. Highway 91 are the primary access routes to the Shoshone-Bannock Reservation. U.S. Highway 20 and U.S. Highway 26 are the main access routes to the southern portion of the INEL site. Idaho state routes 22, 28, and 33 pass through the northern portion of the INEL; State Route 33 provides access to the northern INEL site facilities. Table 4-25 lists the baseline (1991) traffic for several of these access routes.

Table 4-25. Baseline Traffic for Selected Highway Segments^(a) on the Idaho National Engineering Laboratory

Route	Average Daily Traffic	Peak Hourly Traffic ^(b)
U.S. Highway 20-Idaho Falls to INEL	2290	344
U.S. Highway 20/26-INEL to Arco	1500	225
U.S. Highway 26-Blackfoot to INEL	1190	179
State Route 33 West from Mud Lake	530	80
Interstate 15-Blackfoot to Idaho Falls	9180	1380
(a) Source: DOE 1995o.		
(b) Estimated as 15% of average daily traffic.		

The level of service of these segments is currently designated free flow, defined as "operation of vehicles is virtually unaffected by the presence of other vehicles."

The INEL has developed an onsite road system of approximately 140 km (87 mi) of paved surface, including about 29 km (18 mi) of service roads that are closed to the public. Most of the roads are adequate for the current level of normal transportation activity and could handle some increased traffic volume. The DOE plans to reconstruct several deteriorating INEL roads built in the 1950s that have been and will continue to be used to transport heavier-than-normal loads.

Approximately 4000 DOE and contractor personnel administer and support INEL work at offices in Idaho Falls. DOE shuttle vans provide hourly transport between in-town facilities. One of the busiest intersections is Science Center Drive and Fremont Avenue, which serves Willow Creek Building, Engineering Research Office Building, INEL Electronic Technology Center, and DOE office buildings. This intersection is congested during peak weekday hours, but it is designed for the current traffic.

Four major modes of transit use the regional highways, community streets, and INEL site roads to transport people and commodities: DOE buses and shuttle vans, DOE motor pool vehicles, commercial trucks, and personal vehicles. Table 4-26 summarizes the baseline miles for INEL-related traffic.

Table 4-26. Baseline Annual Vehicle Miles Traveled for Idaho National Engineering Laboratory-Related Traffic^(a)

Mode of Travel and Transportation	Vehicle Miles Traveled ^(b)
DOE Buses	6,068,200
Other DOE Vehicles	9,183,100
Commercial Trucks	56,000
Personal Vehicles on Highways to INEL	7,500,000
Total	22,807,300
(a) Source: DOE 1995o.	
(b) To convert miles to kilometers, multiply by 1.61.	

4.4.11.2 Airports and Air Traffic

Commercial airlines provide Idaho Falls with jet aircraft passenger and cargo service, as well as commuter service to the Idaho Falls and Pocatello airports. In addition, local charter service is available in Idaho Falls, and private aircraft use the major airport and many other fields in the area. Total landings at the Idaho Falls airport for 1991 and 1992 were 5367 and 5598, respectively. The Idaho Falls and Pocatello airports collectively record nearly 7500 landings annually.

Non-DOE air traffic over the INEL site is limited to altitudes higher than 305 m (1000 ft) over buildings and populated areas, and non-DOE aircraft are not permitted to use the site. The primary air traffic at the INEL site is DOE helicopters, which are used for security and emergency purposes. These helicopters have specific operations stations and duties.

4.4.12 Radiological Health and Safety

For general information applicable to the four alternatives, refer to Section 3.0.

Radioactivity released to the air can result in human exposure through a number of pathways, including inhalation, external exposure, and ingestion. The DOE conducts physical measurements and uses calculation techniques to assess existing levels of radiation in and near the INEL site and to assess radiological doses to workers and the surrounding population.

The estimated potential population dose was 0.3 person-rem (3×10^{-3} person-Sv) to a population of approximately 121,500 within 80 km (50 mi) of the site. No (0.00015) latent cancer fatalities are expected

from this population dose. Using the CAP-88 code and the MESODIF code, the maximally exposed individual was calculated to receive 0.011 mrem and 0.03 mrem, respectively, from 1993 INEL operations (Mitchell 1994). The MESODIF results are tabulated in Table 4-27.

Table 4-27. Maximum Individual Effective Dose Equivalent from 1993 Idaho National Engineering Laboratory Emissions to the Air (taken from Mitchell 1994)

Radionuclide	Maximum Effective Dose Equivalent	
	mrem	mSv
Iodine-129	2.6×10^{-2}	2.6×10^{-4}
Argon-41	1.4×10^{-3}	1.4×10^{-5}
Krypton-88 + D ^(a)	2.9×10^{-4}	2.9×10^{-6}
Strontium-90 + D ^(a)	1.4×10^{-4}	1.4×10^{-6}
Cesium-137 + D ^(a)	1.4×10^{-4}	1.4×10^{-6}
Xenon-135	1.3×10^{-3}	1.3×10^{-5}
Xenon-133	3.2×10^{-5}	3.2×10^{-7}
Krypton-85	3.1×10^{-5}	3.1×10^{-7}
Xenon-138 + D ^(a)	2.2×10^{-5}	2.2×10^{-7}
Hydrogen-3	1.9×10^{-5}	1.9×10^{-7}
Krypton-85m	1.1×10^{-5}	1.1×10^{-7}
Total	2.9×10^{-2}	2.9×10^{-4}
(a) The D notation indicates decay products are included in this dose equivalent.		

Workers at major INEL facilities may receive radiological exposures. The largest fraction of the occupational dose received by INEL workers is from external radiation. The maximum dose received by a worker, from the air pathway, at any onsite area is about 4.3 mrem per year (DOE 1995o). This dose value of 4.3 mrem per year includes the maximum projected operation of the Portable Water Treatment Unit at the Power Burst Facility area. However, operation of that facility would be temporary (expected to last 1 to 2 years) and is not representative of a permanent increase on the baseline. If this facility were not included, the baseline dose to workers would be about 0.2 mrem per year (DOE 1995o).

From 1987 to 1991, the average occupational dose to individuals who had received measurable doses was 0.156 rem per year, resulting in an average collective dose of about 300 person-rem. The resulting number of expected excess health effects would be less than one for each year of operation (DOE 1995o).

4.4.13 Site Services

Major utility systems on the INEL site include water and sanitary sewer pipelines. A system of about 30 wells, with pumps and storage tanks, provides the water supply for the INEL site. Because of the distance between site facility areas, the water supply system for each facility is independent. The site uses no natural surface water. The city of Idaho Falls water supply system, which includes about 16 wells, provides water to DOE and contractor facilities in the city.

A Water Rights Agreement between DOE and the state of Idaho regulates groundwater use at the INEL site. Under this agreement, INEL has claim to 2300 L per second (36,000 gal per minute) of groundwater, not to exceed 43 billion L (11 billion gal) per year (Teel 1993). The DOE has not measured the total pumping rate from the aquifer, which would depend on the number of pumps operating. A slight possibility exists that the site could exceed the regulated pumping rate for very short periods, such as during recovery from an extended power outage when many pumps would run to refill depleted storage tanks.

For 1987 through 1991, the average water consumption by the INEL site was 7.4 billion L (1.9 billion gal) per year, based on the cumulative volumes of water withdrawn from the wells (Teel 1993). The projected baseline usage for 1995 will be about 6.5 billion L (1.7 billion gal). The estimated average water consumption of Idaho Falls facilities is 300 million L (80 million gal) per year.

The Antelope substation supplies commercial electric power to the INEL site through two feeders to the federally owned Scoville substation. The Scoville substation supplies electric power directly to the INEL electric power distribution system. The contract with Idaho Power Company to supply electric power to the INEL site provides "up to 45,000 kW monthly" at 13.8 kV (IPC/DOE 1986). Hydroelectric generators along the Snake River in southern Idaho and the Bridger and Valmy coal-fired thermal electric generation plants in southwestern Wyoming and northern Nevada, respectively, generate the electric power supplied by Idaho Power.

The rated capacity of the INEL site power transmission loop line is 124 MW. The peak demand on the system from 1990 through 1993 was about 40 MW, and the average usage was slightly less than 217,000 MWh (Table 4-28). This usage rate should decrease by about 4% by 1995.

The INEL facilities in Idaho Falls receive electric power from the city of Idaho Falls, which operates four hydroelectric power generation plants on the Snake River along with substation and distribution facilities. The Bonneville Power Administration, which operates hydroelectric plants on the Columbia River system, supplies supplemental power to the city of Idaho Falls. In 1993, Idaho Falls facilities used 31,500 MWh of electricity.

Fuels consumed at the INEL site include several liquid petroleum fuels, coal, and propane. All fuel is transported to the site for storage and use. Natural gas is the only reported fuel consumed at the INEL

Table 4-28. Existing Idaho National Engineering Laboratory Utility Resource Requirements

Utility Resources	Average Annual Consumption	Peak Demand	System Capacity
Electricity	217,000 MWh	40 MW	300 MW
Water	1.94 billion gal	5000 gpm	17,000 gpm
Conversion: To convert gallons (gal) to liters (L), multiply by 3.785.			

Idaho Falls facilities; the Intermountain Gas Company provides this fuel through a system of underground lines. Fuel storage is provided at each facility, and inventories are restocked as necessary. No fossil fuel shortage has ever occurred at the INEL site. See Table 4-29 for average annual fuel consumption at the INEL site from 1990 through 1993.

Table 4-29. Existing Idaho National Engineering Laboratory Fuel Resource Requirements

Utility Resources	Average Annual Consumption
Fuel Oil	2,795,000 gal
Diesel Fuel	1,500,000 gal
Propane Gas	150,000 gal
Coal	9,000 tons
Conversion: To convert gallons (gal) to liters (L), multiply by 3.785.	

4.4.14 Waste and Spent Nuclear Fuel Management

The INEL is a multipurpose facility supporting efforts in nuclear safety, reactor development, reactor operations and training, waste management, technology development, and technology transfer programs. These activities have resulted in the generation of radioactive, hazardous, and mixed waste.

This section summarizes the management of materials and wastes (high-level, transuranic, mixed low-level, low-level, hazardous, industrial and commercial solid wastes, and hazardous materials) at the INEL and Idaho Falls facilities and presents an overview of the current status of the various waste types generated, stored, and disposed of at the INEL.

The total amount of waste generated and disposed of has been reduced through waste minimization and treatment. The INEL attains waste minimization by reducing or eliminating waste generation, by recycling, and by reducing the volume, toxicity, or mobility of waste before storage or disposal. In addition, the site has achieved volume reduction of radioactive wastes through more intensive surveying, waste segregation, and use of administrative and engineering controls.

The information presented in this section is taken directly from the SNF-PEIS (DOE 1995o), unless otherwise noted.

4.4.14.1 Spent Nuclear Fuel

Spent nuclear fuel currently is received from, and will continue to be received from, the Naval nuclear program and the Advanced Test Reactor on the INEL. Fuel currently stored at INEL has come from these sources, other government and university research reactors, and special-case commercial reactors. Upon implementation of the SNF PEIS record of decision, INEL may receive additional spent nuclear fuel from other DOE sites.

Spent nuclear fuel is stored in water-filled, fuel storage basins at various facilities throughout INEL. Some dry storage is also available. The facilities in which most of the spent nuclear fuel is stored are the Idaho Chemical Processing Plant, the Power Burst Facility, and a storage pool at the Test Area North. The Test Area North storage pool was built in the 1950s and is not considered adequate for long-term interim storage. Spent nuclear fuel may be removed and transferred to dry storage by fiscal year 2000. The CPP-603 storage pools in the Idaho Chemical Processing Plant and the pool in the Power Burst Facility also will be emptied. DOE is evaluating consolidating all INEL special nuclear fuels at the Idaho Chemical Processing Plant (DOE 1995k). The quantity of spent nuclear fuel at the INEL in 1995 was estimated as about 261,000 kg (heavy metal) (DOE 1995b).

4.4.14.2 Low-Level Radioactive Waste

Through 1991, DOE disposed of 145,000 m³ (190,000 cu yd) of low-level waste at the Radioactive Waste Management Complex. In 1991, the total available low-level waste disposal capacity at the complex was 37,000 m³ (48,000 cu yd) (DOE 1995b, Volume 1, Appendix B). As of 1993, INEL had approximately 147,000 m³ (192,000 yd³) of low-level waste with a 1993 annual produced volume of 900 m³ (1200 yd³) (DOE 1994b).

4.4.14.3 Low-Level Mixed Waste

At present, DOE accepts only low-level mixed waste generated at the INEL for treatment and disposal at the INEL. DOE stores low-level mixed waste generated at the INEL at interim storage facilities until treatment systems become available or operational. A total of 1800 m³ (2400 yd³) of low-level mixed waste interim storage capacity is available at the INEL. Current low-level mixed waste interim storage is

approximately 1100 m³ (1400 yd³). Treatment technologies exist for much of the low-level mixed waste generated at the INEL, and waste minimization eliminates potential sources of low-level mixed waste before generation. The projected 1995 baseline for low-level mixed waste is 525 m³ (687 yd³) annually.

5.0 Environmental Consequences

5.1 Overview

The consequences of producing molybdenum-99 (Mo-99) and associated medical isotopes at U.S. Department of Energy (DOE) facilities are evaluated in this section. Activities considered include fabrication of targets containing highly enriched uranium, irradiation of the targets in a DOE reactor facility, processing of the targets to recover Mo-99 and other medically useful isotopes (such as iodine-131 and xenon-133), transport of waste for disposal, and transport of the isotopes to radiopharmaceutical manufacturers where the materials are prepared for medical use. Iodine-125 production, using a separate target system, is considered as well. Iodine-125 is produced by activation of nonradioactive xenon-124, as opposed to the fission targets used for producing Mo-99. The impacts of producing iodine-125, wherever such impacts differ from those of Mo-99, are included in the analysis contained in this section. The assessment includes activities necessary to prepare or modify existing facilities at the DOE sites under consideration to undertake the medical isotope production mission.

The no action alternative would not result in any additional environmental impact at any DOE site. The activities and missions at the candidate DOE facilities would, therefore, remain as described in Section 4.0. The only potential consequences of the no action alternative would be to the U.S. health care community and its consumers. These impacts would take the form of increased cost and risk to patients from lack of diagnostic procedures, or from use of alternative procedures, in the event that the Canadian source of Mo-99 for metastable technetium-99 (Tc-99m) generators became unavailable for an extended time and another supply was not available to meet current needs.

The impacts of producing medical isotopes at DOE facilities would vary, depending on the location and the status of existing facilities that would be converted for use in the production mission. However, the processes for target production and recovery of the isotopes would be similar wherever they might be conducted because of the need to conform to previously approved U.S. Food and Drug Administration (FDA) procedures for manufacture of medical radioisotopes. The reactor facilities for irradiation of the targets are generally of similar design, but each has unique features and operating characteristics because of the different purposes for which they were constructed. The extent of activity necessary to modify operating reactors, to restart shutdown reactors, or to prepare hot cell facilities for target fabrication and processing would also vary from site to site.

Impacts on the environment due to facility modifications would be minimal because existing facilities at all sites would be converted to the isotope production mission. Therefore, substantial effects on land use, cultural resources, aesthetic and scenic resources, geological resources, ecological resources, and community noise levels would not be expected at any site. The effect on economic climate and community resources would also be minimal because of the relatively small number of workers that would be employed in the isotope production project.

The environmental impacts of the proposed action would result from effluents released to air from facilities during routine operation, and from transportation of isotopes to radiopharmaceutical manufacturers. The consequences of these activities for workers and the public would be well within regulatory guidelines. Relatively small quantities of materials and other resources would be consumed by modifications to the facilities, and from operation of the isotope production and recovery process. The process would also generate low-level radioactive waste, which would be temporarily stored at the generation site to allow decay of short-lived radionuclides, followed by disposal either onsite (in the case of Los Alamos National Laboratory [LANL] or Idaho National Engineering Laboratory [INEL]) or at another DOE site (in the case of Sandia National Laboratories/New Mexico [SNL/NM] or the Oak Ridge National Laboratory [ORNL]). Under any alternative, less than 0.1 m³/yr (3.5 ft³) of mixed waste is expected to result from the process. Spent nuclear fuel from operation of the reactors would be kept in interim storage at the generation sites or at regional storage facilities until DOE makes a decision on its ultimate disposition (that is, whether to reclaim its energy resources for beneficial, non-defense purposes or to dispose of it permanently in a geologic repository). Accidents have the potential to result in health effects. However, the risk of such events, accounting for the estimated accident frequencies, is sufficiently low that no health impacts would be anticipated for any reasonable duration of the project.

As proposed, the medical isotope project would produce only a small fraction (10-30%) of the U.S. demand on a continuing basis to maintain staff and facility capabilities, unless the Canadian supply was interrupted. In that event, the production rate would increase to supply the entire domestic demand. The analysis in this Final Environmental Impact Statement (FEIS), therefore, considers operation at 100% of the capacity required to supply U.S. needs to provide a bounding analysis of the potential consequences.

Because the DOE intends to produce Mo-99 even while the Canadian source is supplying Mo-99, periods may occur when the DOE is unable to sell the Mo-99 that it produces. In this case, the unsold Mo-99 would have to be disposed of as low-level radioactive waste. The disposal of unsold Mo-99, with the other low-level radioactive waste generated during production, is bounded by the analyses in this FEIS.

This section of the FEIS is organized by consequence type, with the alternatives discussed sequentially under each impact category. This organization permits a more direct comparison of the alternatives for each type of potential consequence associated with the medical isotope production project.

5.2 Land Use

Medical isotope production would use existing, in some cases inactive, DOE facilities with relatively minor modification, and would not necessarily preclude concurrent use of the candidate facilities for research or other compatible missions. The planned facility modifications at SNL/NM are the most extensive required at any site, and consist of replacement of the Annular Core Research Reactor cooling tower, possible addition of a second cooling tower, installation of a backup generator for the reactor, extension of the reactor high bay to install an airlock, and expansion of the ventilation system for the hot

cell facility. The total area required for these modifications to existing facilities is estimated to be 210 m² (2300 ft²) (DOE 1994b) with a total disturbed area roughly twice that size. If a new hot cell facility were constructed at INEL, land use might be greater than at SNL/NM; however, it would also be located within or adjacent to an existing facility in a previously developed area. Facility upgrades at LANL and ORNL would involve only replacement or modification of existing structures, and therefore would not represent new land use at these sites.

Typically, impacts on land use would not be expected other than for projects that require appropriation of large tracts of land that are suited for multiple uses, and for which there are competing interests. Therefore, commitment of existing facilities to provide a domestic backup capability for production of medical isotopes would be unlikely to create conflicts with regard to land use under any of the alternatives considered in this FEIS.

5.3 Socioeconomics

The socioeconomic impacts are classified in terms of primary and secondary effects. Changes in employment and expenditures associated with the production of Mo-99 are classified as primary effects; the additional changes in the general regional economy and community, as a result of these primary changes, are classified as secondary effects. Examples of secondary impacts include such changes as those in retail and service employment or changes in demand for housing. The total socioeconomic impact in the region is the sum of the primary and secondary impacts.

Table 5-1 provides the available information on year-by-year costs and labor requirements for facility modifications and operations for each alternative considered. Current estimates place total costs to modify and restart facilities included in the various options at \$17.2 million to \$21 million, with annual operating costs eventually (FY 1999+) averaging from \$8.4 million to \$12.8 million per year (See Section 5.22). Peak startup employment is between 50 and 60 full-time equivalent employees (FTEs), with operations employment between 45 and 65 FTEs. These ranges represent net differences in employment from what otherwise would have occurred. Some jobs may represent transfers of existing residents rather than new migrants. At this point, the alternative of having target production at SNL/NM is considered not to have significantly different cost and employment from the alternative shown. Thus, the difference in its potential socioeconomic impact is expected to be negligible as well. The location of impacts would be slightly different if target production occurs at SNL/NM rather than LANL, but only \$1 million in costs and about five employees would be shifted to SNL/NM.

Estimates of total employment and income impacts were calculated using the Regional Input-Output Modeling System (RIMS II) multipliers produced by the U.S. Bureau of Economic Analysis (U.S. Department of Commerce 1986) for the local area whose economy and population are affected by Mo-99 production. This area, called the region of influence, is a multi-county area that is linked economically and socially. The region of influence varies in geographical size and shape from site to site, and even by type

**Table 5-1. Cost and Labor Estimates for Facility Modification
and Operation of the Various Alternatives^(a)**

Costs by Alternative		FY 1996	FY 1997	FY 1998	FY 1999+
SNL/NM Alternative					
Facility Costs ^(b)	Startup Labor	\$2.6	\$5.7	\$1.3	\$0.0
	Startup Goods Services	2.7	5.9	1.4	0.0
	Operations Labor	0	0	8.6	8.6
	Operations Goods Services	0	0	4.2	4.2
Total		\$5.3	\$11.6	\$15.5	\$12.8
Labor Requirement ^(c)	Startup Labor	25	55	12	0
	Operations Labor	0	0	59	59
	Total	25	55	71	59
LANL Alternative					
Facility Costs ^(b)	Startup Labor	\$5.3	\$6.4	\$0	\$0
	Startup Goods Services	3.6	4.4	0	0
	Operations Labor	0	0	8.0	8.0
	Operations Goods Services	0	0	3.0	3.0
Total		\$8.9	\$10.8	\$11.0	\$11.0
Labor Requirement ^(c)	Startup Labor	41	51	0	0
	Operations Labor	0	0	45	45
	Total	34	40	45	45
ORNL Alternative					
Facility Costs ^(b)	Startup Labor	\$6.4	\$8.0	\$1.5	\$0
	Startup Goods Services	3.2	1.4	0.5	0
	Operations Labor	0	0	5.2	6.4
	Operations Goods Services	0	0	3.2	3.2
Total		\$9.6	\$9.4	\$10.4	\$9.6
Labor Requirement ^(c)	Startup Labor	47	59	7	0
	Operations Labor	0	0	60	62
	Total	47	59	67	62
INEL Alternative					
Facility Costs ^(b)	Startup Labor	\$6.7	\$7.9	\$0	\$0
	Startup Goods Services	1.2	1.5	0	0
	Operations Labor	0	0	6.7	6.7
	Operations Goods Services	0	0	1.7	1.7
Total		\$7.9	\$9.4	\$8.4	\$8.4
Labor Requirement ^(c)	Startup Labor	43	54	0	0
	Operations Labor	0	0	59	59
	Total	43	54	59	59
(a) Totals may differ from figures in Section 5.22 because of rounding.					
(b) Costs are expressed in millions of 1995 dollars.					
(c) Labor figures are presented in terms of full time equivalent employees required.					

of project. For the purposes of this analysis, the construction activity for the proposed alternative was represented by the New Construction industry, and the operations phase activities are represented by the Business Services industry. The primary and secondary impacts together varied from 100 to 300 total regional jobs and from \$3 million to \$6 million in annual regional income, generally less than 0.1% of the corresponding regional totals.

Impacts other than employment and income were based on changes in population, in view of current capacities of the local roads, schools, waste and water treatment, and other elements of local infrastructure. Historical geographic patterns of settlement are assumed to persist. When compared to the baseline regional employment, population, and personal income in each region of influence, the percentage changes expected as a result of applying the RIMS II multipliers are less than 0.12% in every case. Based on experiences in boomtowns, a useful rule of thumb is that 5% growth is as much growth as a small community can comfortably manage (Gilmore and Duff 1975). While conditions can vary from community to community, population increases significantly less than this are usually within the capacities of communities to absorb. The larger and less-isolated a community (as when it is next to a large metropolitan area), the greater this capacity to manage growth. Because the estimated change in population for any given year is two orders of magnitude smaller and spread over several communities, sufficient capacity for community services would be expected. The potential impacts on the adequacy of community resources and services, such as housing, schools, police, health care, and fire protection, also would be negligible under any alternative.

5.4 Cultural Resources

None of the alternatives considered in this FEIS would involve excavation or land disturbance in previously undeveloped areas of the candidate sites; therefore, the opportunity for discovery of sites or artifacts that may be of cultural significance to Native American peoples or other ethnic groups is very low. If items of potential cultural or historical importance were discovered during facility modification or expansion, work would be suspended and the disposition of the find would be determined in consultation with representatives of appropriate cultural or ethnic groups and regulatory agencies.

None of the facilities under consideration for use in the isotope production mission are currently listed on the National Register of Historic Places, although the Omega West Reactor was previously under consideration and some of the other facilities might eventually be eligible for nomination in the future. If major modification of these facilities were expected, such activities would be carried out in accordance with the National Historic Preservation Act and guidance from state historic preservation officers to preserve any information that might have historic value.

5.5 Aesthetic and Scenic Resources

Impacts on aesthetic or scenic resources generally result from major construction activities in regions where such resources exist. The consequences of such activities could result from the presence or appearance of the completed facility that detracts from the scenic value of the region, or from air emissions that might obscure the resource during construction or operations. Because of the limited extent of the construction associated with any of the alternatives evaluated in this EIS, as well as the location of candidate facilities in established complexes within DOE sites, no impacts on aesthetic or scenic resources would be expected. Construction of cooling towers to augment or replace existing structures would likewise be unlikely to represent a substantial degradation of the scenic value of the sites involved because of their location in previously developed or remote areas of the candidate sites, adjacent to similar structures. The limited facility modifications would be unlikely to require extensive additions to services, such as lighting or electrical transmission towers.

5.6 Geologic Resources

Impacts on geologic resources would not be expected because the project's requirements would not result in depletion of scarce minerals with multiple uses, nor would it involve other activities that might make those resources unavailable. The geologic resource requirements for any of the proposed alternatives consist of modest quantities of construction materials, such as gravel, cement, metals, and other minerals. These materials are not scarce resources for which there are competing uses; therefore, no detrimental effects on geologic resources would be anticipated.

5.7 Air Quality

Effects of the alternatives on air quality are considered in this section. Emissions to air under any of the alternatives would consist primarily of radionuclides from the reactors, and isotope recovery and purification facilities. Emissions of nonradioactive or hazardous materials would not be expected under normal operating conditions for any of the alternatives, and construction activities are limited in scope such that emissions of fugitive dust or exhaust from equipment would not be expected to have widespread impacts over the long term. Vehicle emissions from target, isotope, or waste shipments would be very small compared to those from normal traffic at any of the candidate sites. Therefore, no changes in non-radiological air quality would be expected under any alternative. Health effects of vehicle emissions are considered in Section 5.11.

The radiological consequences of air emissions during normal operation have been estimated for the alternatives considered in this document. The radiological doses were evaluated using the GENII computer code package (Napier et al. 1988) (see Appendix C). Three separate analyses were performed for each facility included in a particular alternative. The receptors evaluated in these cases were 1) at the

location of maximum air concentration representing a potential onsite worker outside of the facility, 2) the maximally exposed offsite resident, and 3) the collective population within 80 km (50 mi).

In general, the maximally exposed individual (MEI) was hypothesized to have a lifestyle that maximized exposure to radioactive air effluents from nearby facilities. The MEI's location was identified from annual environmental monitoring reports and used as input into the model results reported in this analysis. The MEI is assumed to be exposed to and to breathe the contaminated plume all year (8766 h), to spend 50% of the year on contaminated soil, and to consume locally grown food.

Individual worker doses were calculated based on a 2000-h exposure to the contaminated plume, 2000 h of inhalation, and 200-h exposure to contaminated soil. These parameters were chosen because on average a worker spends approximately 2000 h per year at work where exposure to and inhalation of the plume is probable. The 200-h exposure to contaminated soil is a conservative estimate of the worker's time spent outdoors on contaminated soil. In the worker scenario, consumption of contaminated food and water was not considered because these commodities are generally produced at locations remote from the workplace.

The health consequences in terms of cancer fatalities were calculated based on collective population dose using recommendations of the International Commission on Radiological Protection in its Publication 60 (ICRP 1991). The health effects from low-dose radiological exposures are taken to be 5×10^{-4} fatal cancers/person-rem for the general population and 4×10^{-4} fatal cancers/person-rem for workers. In the tables that follow in this section, latent cancer fatalities less than one in the affected population are shown as the actual calculated value, although it is recognized that health effects in this range would not be observed. Other types of health effects would occur at lower rates (for example, non-fatal cancers or genetic effects), or would only be expected at much higher doses than those estimated for the types of activities discussed in this FEIS (for example, cataracts or reproductive effects).

Estimates of latent fatal cancers resulting from facility operations are presented only for collective populations in this analysis. The dose-to-cancer risk factors were not applied to individual radiation dose estimates because the exposure levels and the response of individuals to those exposures are sufficiently uncertain that such estimates would be meaningless. The cancer risk estimates for radiation exposures are based on modes and levels of exposure (primarily to Japanese atomic bomb survivors and individuals undergoing specific types of medical treatments) that are very different from those expected for the types of environmental exposures considered in this analysis. These estimates are used in this evaluation to provide an approximation of the type and extent of health effects that might occur as a result of the proposed activities; however, they are presented with the provision that the estimates are subject to substantial uncertainty and are likely to be conservative (that is, to overestimate the health effects associated with environmental radiation exposures).

The estimated radionuclide air emissions from facilities during medical isotope production, and their consequences for onsite workers and the public, are described in the following sections for the sites evaluated in this FEIS. Target fabrication was assumed to result in negligible air emissions at all sites

because the process is entirely contained in a glove box for which the effluent air is filtered. Emissions of radionuclides during irradiation of targets in reactors was modeled using facility-specific release rates and building parameters where available. Emissions from the target processing facilities were assumed to be similar at most sites because each would use the same process, except where specific process modifications would be applied as noted in the alternative discussions. However, site- and facility-specific data were used to model atmospheric dispersion of the effluents under each alternative. Offsite consequences to the public were estimated using wind data and population distributions appropriate to each site and facility under consideration. Annual average atmospheric dispersion conditions were assumed for all routine air emissions because they would occur continuously throughout the duration of operations to produce medical isotopes.

5.7.1 Annular Core Research Reactor: Sandia National Laboratories/New Mexico and the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

This section evaluates the impacts to human health resulting from radionuclide emissions associated with the proposed Mo-99 production under the SNL/NM alternative. The emissions to the atmosphere from the Annular Core Research Reactor are listed in Table 5-2. Estimated air emissions from the Annular Core Research Reactor are based on historical data, accounting for the proposed changes to the reactor

Table 5-2. Estimated Annual Air Emissions from the Annular Core Research Reactor During Target Irradiation (Massey et al. 1995)

Radionuclide	Quantity (Ci)
Tritium	2.2
Argon-41	2.2

operations associated with production of medical isotopes (Massey et al. 1995). Tritium emissions would increase from the levels experienced in past operations because of the higher operating power and increased time in operation. Argon-41 emissions would decrease compared to historical experience because removal of the air-filled test cavity from the core would reduce the opportunity for neutron activation of stable argon in air. Convection cooling of the reactor also reduces the quantity of air in the cooling water compared to systems that actively pump water through the core.

The radiological dose to the MEI living 5.4 km (3.4 mi) north of the stack release is 0.00017 mrem (see Table 5-3). The controlling dose pathway was external exposure from the gas argon-41.

Emissions from the Annular Core Research Reactor stack were modeled using a 17 m (56 ft) release height, an inner radius of 0.1 m (0.3 ft), and a flow rate of 0.35 m³/s (740 cfm). The hot cell stack was modeled as 38 m (125 ft) high with an inner radius of 0.9 m (2.9 ft), and a flow rate of 22.1 m³/s (1740 cfm).

Table 5-3. Annual Radiological Dose and Consequences from Routine Air Emissions from the Annular Core Research Reactor During Target Irradiation and Post-Irradiation Processing in the Hot Cell Facility

Receptor	Annular Core Research Reactor	Hot Cells
Offsite Resident (maximally exposed individual) Dose	1.7×10^{-4} mrem	0.17 mrem
Onsite Worker Dose	1.1×10^{-4} mrem	0.037 mrem
Offsite Population Dose	0.023 person-rem	13 person-rem
Latent Fatal Cancers in Offsite Population	1×10^{-5}	0.007

Target fabrication was estimated to result in negligible air emissions because the process occurs entirely in a filtered glove box. The operation involves plating uranium from solution onto the inner surface of a stainless steel tube to produce the target. No mechanism was identified by which measurable release of the uranium solids or solution from the glove box could occur during normal operations.

Estimated air emissions from target processing at the hot cell facility consist of volatile iodine and noble gases, as listed in Table 5-4. The estimated emissions from the hot cell are based on the most recent historical emissions from the Cintichem process (NRC 1984) adjusted for the relative quantities of Mo-99 production at the facilities. These estimates assume emission controls comparable to those used by the Cintichem facility, consisting of high efficiency particulate air (HEPA) filters and a charcoal bed to trap iodine. They are, therefore, relatively conservative because the emission controls at DOE hot cells would meet or exceed the level of those used at the Cintichem facility. The estimated doses from target processing are shown in Table 5-3 and amount to 0.17 mrem to an offsite resident 5.4 km (3.3 mi) north of the facility.

5.7.2 Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

This section evaluates the impacts to human health resulting from radionuclide emissions associated with the proposed Mo-99 production under the LANL alternative. The emissions to the atmosphere from the Omega West Reactor were estimated to be 953 Ci/yr of argon-41 (LANL 1993e). The MEI was located approximately 580 m (634 yd) north-northwest of the Omega West Reactor stack. The radiological dose to this MEI was calculated to be 0.15 mrem (see Table 5-5). The controlling dose pathway was external exposure from the argon-41. Emissions from the Omega West Reactor stack were modeled using a stack height of 46 m (151 ft), an inner radius of 0.1 m (0.3 ft), and a flow rate of $0.38 \text{ m}^3/\text{s}$ (800 cfm).

Table 5-4. Estimated Annual Radionuclide Emissions from Hot Cell Facilities During Processing of Irradiated Targets for Molybdenum-99 Extraction

Radionuclide	Quantity Released (Ci)
Krypton-83m	660
Krypton-85m	970
Krypton-85	6.3
Krypton-87	190
Krypton-88	1600
Iodine-131	3.9
Iodine-132	10
Iodine-133	18
Iodine-134	0.72
Iodine-135	11
Xenon-131m	5.9
Xenon-133m	340
Xenon-135m	16,000
Xenon-133	7200
Xenon-135	6900

Table 5-5. Annual Radiological Dose and Consequences from Routine Air Emissions from the Omega West Reactor During Target Irradiation and Post-Irradiation Processing at the Chemistry and Metallurgy Research Facility

Receptor	Dose From Omega West Reactor	Hot Cell Facility
Offsite Resident (MEI) Dose	0.15 mrem	0.0042 mrem
Onsite Worker Dose	0.012 mrem	0.00015 mrem
Offsite Population Dose	0.63 person-rem	0.032 person-rem
Latent Fatal Cancers in Offsite Population	3×10^{-4}	2×10^{-5}

Target processing at LANL would employ emission controls in addition to those assumed for the releases listed in Table 5-4. At LANL, the hot cell would be designed to process Mo-99 targets entirely within a sealed system, and volatile gases released during the process would be trapped and stored to allow decay of short-lived fission products. Although the process has not been demonstrated on a production scale, it is assumed that radioactive iodine, particulates, and short-lived noble gases could be completely contained within sealed containers during the designated decay period, after which the storage containers would be reused. Allowing for a minimum 50-day decay time, the longer-lived noble gases released to the atmosphere via the hot cell facility stack would amount to 85 Ci/yr of krypton-85, 36 Ci/yr of xenon-131m,

and 1200 Ci/yr of xenon-133 for a Mo-99 production rate sufficient to supply 100% of the U.S. demand. Based on these release rates, the dose to the offsite MEI from target processing would be 0.0042 mrem/yr at a location 1 km (0.6 mi) north of the Chemistry and Metallurgy Research facility (see Table 5-5). Emissions from the Chemistry and Metallurgy Research facility during target processing were modeled using a stack height of 16.6 m (54 ft), a flow rate of 52.9 m³/s (114,000 cfm), and an inner radius of 2.6 m (8.7 ft) (DOE 1994f).

5.7.3 Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory Alternative

This section evaluates the impacts to human health resulting from radionuclide emissions associated with the proposed Mo-99 production under the Oak Ridge Research Reactor alternative. The Oak Ridge Research Reactor was estimated to release 950 Ci/yr of argon-41 to the atmosphere under normal operating conditions during target irradiation. The radiological dose to the MEI living 5.4 km (3.35 mi) east of the stack release, is 0.004 mrem/yr (see Table 5-6). The controlling dose pathway was external exposure from the argon-41.

Table 5-6. Annual Radiological Dose and Consequences from Routine Air Emissions from the Oak Ridge Research Reactor During Target Irradiation and Post-Irradiation Processing in ORNL's Hot Cell Facility

Receptor	Dose from Oak Ridge Research Reactor	Hot Cell Facility
Offsite Resident (MEI) Dose	0.004 mrem	0.31 mrem
Onsite Worker Dose	0.00036 mrem	0.022 mrem
Offsite Population Dose	0.41 person-rem	15 person-rem
Latent Fatal Cancers in Offsite Population	2×10^{-4}	0.008

The Oak Ridge Research Reactor stack and the Hot Cell facility were modeled using a stack height of 76 m (249 ft), an inner radius of 2.8 m (9.2 ft), and a flow rate of 66 m³/s (140,000 cfm) (DOE 1995o). The emissions during target processing at the hot cells are listed in Table 5-4, resulting in a dose of 0.31 mrem/yr to the offsite MEI (Table 5.6).

5.7.4 Power Burst Facility/Test Area North: Idaho National Engineering Laboratory Alternative

This section evaluates the impacts to human health resulting from radionuclide emissions associated with the proposed Mo-99 production under the INEL alternative. Emissions to the atmosphere from the

Power Burst Facility were estimated from historic stack monitoring data scaled up to the integrated power requirements for production of medical isotopes (see Table 5-7).

Table 5-7. Estimated Annual Air Emissions from the Power Burst Facility During Target Irradiation

Radionuclide	Quantity (Ci)
Argon-41	620
Strontium-90	7×10^{-6}
Cobalt-60	7×10^{-6}
Cesium-134	1×10^{-5}
Cesium-137	9×10^{-5}
Iodine-131	1×10^{-6}

The radiological dose to the MEI living 12 km (7.5 mi) to the southeast is 0.0013 mrem. The controlling dose pathway was external exposure from the noble gas argon-41. Doses to the maximum worker and the general public from both the Power Burst Facility and the Hot Cell Facility (assumed to be located near the Power Burst Facility) are shown in Table 5-8.

Table 5-8. Annual Radiological Dose and Consequences from Routine Air Emissions from the Power Burst Facility During Target Irradiation and Post-Irradiation Processing in the Hot Cell Facility

Receptor	Power Burst Facility	Hot Cells Facility (Power Burst Facility Location)
Offsite Resident (MEI) Dose	0.0013 mrem	0.13 mrem
Onsite Worker Dose	0.0013 mrem	0.29 mrem
Offsite Population Dose	0.011 person-rem	1.2 person-rem
Latent Fatal Cancers in Offsite Population	7×10^{-6}	6×10^{-4}

Emissions from the Power Burst Facility stack were modeled using a stack height 24 m (79 ft), an inner diameter of 0.45 m (1.5 ft), and a flow rate of 2.8 m³/s (5900 cfm) (DOE 1995b). For the purpose of this portion of the evaluation, the hot cell facility is assumed to be located adjacent to the Power Burst Facility because it would bound the offsite consequences, compared to those that would result if the release occurred at other potential hot cell locations (for example, Test Area North). Estimated emissions from target processing are listed in Table 5-4, resulting in a dose of 0.13 mrem/yr to the offsite MEI.

5.8 Water Quality

No routine releases of liquid effluents to either surface or ground water would occur under any of the alternatives proposed. Therefore, no consequences to water quality would occur from emissions to water supplies at any of the DOE sites considered as a result of normal operations during medical isotope production; water resources would remain as described in Section 4.0.

5.9 Ecological Resources

No ecological impacts are anticipated under any alternative, because activities associated with medical isotope production would occur in previously developed areas of the sites. Therefore, neither plants, animals, nor their habitats (including wetlands) would be adversely affected.

DOE has determined that no adverse effects would occur in aquatic systems or recreational fisheries, as a result of implementing any of the alternatives.

5.10 Noise

| No noticeable increase in noise levels would occur under any of the alternatives.

5.11 Transportation

| This section summarizes the transportation impacts associated with the production of medical isotopes. Further details of this analysis are in Appendix B. The alternatives evaluated have been described in Section 3.0. Potential transportation impacts could include external radiation exposures during routine transport and internal and external exposures due to vehicular accidents that result in a release of radioactive materials. Nonradiological impacts, due to pollutants emitted by the transport vehicles and vehicular accidents that result in injuries and fatalities, are also addressed.

| For each alternative, the routine and accidental radiological and nonradiological impacts associated with transporting unirradiated targets from the target fabrication site to the reactor, transporting irradiated targets from the reactor to a processing facility for separations, and transporting the separated medical isotope from the processing facility to the pharmaceutical distributor were evaluated. Impacts associated with transporting the wastes generated during processing were also addressed. The impacts of transporting spent nuclear fuel are not addressed, because each of the reactor facilities has available spent fuel storage capacity (see Section 5.14). Therefore, no near term impacts would be associated with the transport of spent nuclear fuel from the reactor facilities to an interim or permanent offsite storage facility. The environmental impacts of managing DOE's spent nuclear fuel inventory are addressed in DOE (1995b).

5.11.1 Methods and Assumptions

The following sections describe the assumptions used to evaluate potential of transportation in each of the alternatives. The analysis focuses on the activities associated with transportation of the unirradiated and irradiated targets, medical isotopes, and processing waste. A detailed description of the analyses is provided in Appendix B.

5.11.1.1 Shipping Scenarios

Four transportation scenario alternatives, one for each medical isotopes production alternative, are presented in this evaluation, however, Appendix B provides a detailed analysis of five alternatives, (that is, a separate analysis was performed for each of the SNL/NM target fabrication options). The information presented is based on the shipment of 100% of the U.S. demand for Mo-99 and the associated amounts of related medical isotopes in equal amounts to each of the three U.S. radiopharmaceutical companies. Appendix B also provides transportation information for the shipment of 100% of the product to each of the three U.S. radiopharmaceutical companies. Also evaluated in this section and Appendix B is the shipment of 100% of the product to Nordion International in Canada. It was assumed that all overland transportation would be performed by truck. For example, unirradiated targets would be transported from the fabrication facility to the irradiation facility by truck and final product would be transported to and from the airport by truck. For all alternatives, it was assumed that a maximum of 52 target shipments/yr and a maximum 1140 purified medical isotope shipments/yr or would be required to meet the demand; that is, 100% of the U.S. market. Of the 1140 shipments, 1035 shipments would contain 3 packages each of Mo-99, xenon-133, and iodine-131, and 105 shipments would contain 3 packages of iodine-125. It was also assumed, based on the total number of targets shipped and the assumption that a representative waste cask would contain processing waste from 14 irradiated targets, a maximum of 90 waste shipments/yr would be expected.

Each of the alternatives evaluated is presented in the following list. In addition, for each of the alternatives listed, shipments of the isotopes from the destination airport to the pharmaceutical suppliers (for example, O'Hare to Amersham Medipysics) have been evaluated. A detailed description of each of the shipping scenarios is provided in Appendix B.

- Los Alamos National Laboratory Target Fabrication, Irradiation, Separations, and Shipments from Albuquerque International Airport
- Los Alamos National Laboratory or Sandia National Laboratories Target Fabrication, Sandia National Laboratories Irradiation, Separations, and Shipments from Albuquerque International Airport
- Oak Ridge National Laboratory Target Fabrication, Irradiation, Separations, and Shipments from McGhee Tyson Airport

- Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, and Shipments from Idaho Falls Airport.

5.11.1.2 Shipping System Descriptions

The following sections provide descriptions of the representative shipping cask for unirradiated target shipments, irradiated target shipments, and both overland and air medical isotopes shipments. For all but one of the options (target fabrication at LANL and irradiation and separations at SNL/NM) target transportation would be onsite. However, all shipments would be made by truck and would comply with the appropriate requirements contained in 10 CFR 71 (Type B container) and 49 CFR 173 (Type A container). All air shipments would comply with the requirements contained in 49 CFR 175.

Representative Target Truck Shipping Container and Cask. It was assumed that a target transfer container and shipping cask would be used. A target transfer container can hold up to four irradiated targets. The number of unirradiated or irradiated targets to be shipped at one time would be a maximum of 24 (6 target transfer containers packaged in a cask or 6 casks containing 4 targets each or 2 casks containing 12 targets). Based on a common target design (up to 20 g of 93% enriched uranium-235 [highly enriched uranium] per target) and cask capacity (24 targets per cask) the limits contained in Part 71.22 of 10 Code of Federal Regulations General License: Type A package, Fissile Class III shipment (500 grams per shipment) would not be exceeded.

Representative Separated Medical Isotopes Truck and Air Shipping Cask. The separated medical isotopes would be transported in a Type B shipping cask by truck to the departure airport and from the destination airport to the medical isotope distributors, DuPont-Merck, Amersham Medipysics and Mallinckrodt Medical. It was assumed that a Type B cask similar to a CI-20WC-2 would be used. The cask would be certified for air transport, using commercial passenger or cargo flights. Based on the analysis assumptions (Appendix B), additional shielding could be required for some passenger flights to meet regulatory requirements. This cask may contain up to 1000 Ci of Mo-99/Tc-99m in normal form as solids or liquid, or up to 200 Ci of iodine-131.

The CI-20WC-2 cask is not currently certified for international shipments which would be required for shipments to Nordion. However, often cask designs suitable for transport of Mo-99 product, such as those owned by Nordion, are certified for international transport. The capacities and shielding of the internationally certified casks are similar to those of the CI-20WC-2 cask and would not have a significant effect on the number of shipments and their dose rates. Certification of the CI-20WC-2 cask for international transport is an option, if for some reason the internationally certified casks are unavailable.

Representative Low-Level Waste Truck Shipping Cask. It was assumed that a B-3 Type B package would be used to transport waste packages onsite and on public roadways. This package is suitable for transporting low-level solid radioactive wastes.

5.11.1.3 Transportation Route Information

The transportation routes assumed for this analysis are shown in Table 5-9. The information shown in Table 5-9 includes the number of shipments required, origin, and destination facilities and shipping distances. These data were developed using the HIGHWAY (Joy and Johnson 1992) computer code for truck shipments, or estimated using site maps, and are used to calculate transportation impacts. These data are summarized in Table 5-9 for each transport segment described in Section 5.11.1.1.

5.11.2 Routine or Incident-Free Transportation Impacts

The following sections describe projected radiological and nonradiological impacts during routine or incident-free transportation of unirradiated and irradiated targets, separated isotopes, and secondary waste products for each of the alternatives. A detailed description of the analysis methodology, assumptions, and data is provided in Appendix B.

5.11.2.1 Radiological Impacts from Transportation Activities

This section summarizes the analysis of the radiological impacts to the public and onsite individuals due to routine transportation. Members of the public or onsite individuals exposed to radiation include persons on onsite roads or offsite highways with the shipment, persons residing near these transport links, and persons at intermediate stops along the route (such as refueling stops). For air transport, it was assumed that all shipments would be made using commercial passenger flights with one intermediate stop at a hub. Therefore, impacts to the public include airplane passengers and people in the airport terminals. This additional population will result in conservative estimates relative to cargo air transport, and will bound the impacts of the air transport scenarios. The RADTRAN 4 computer code was used to perform these calculations. A description of RADTRAN 4 is provided in Appendix B.

The results of the public and onsite individual dose calculations, developed using the RADTRAN 4 computer code and the input parameters shown in Table 5-9 and provided in Appendix B are presented in Table 5-10. This table shows the radiological impacts to the combined truck and air transport crew (including handlers at the hubs) and range from 23 to 24 person-rem annually (or 0.01 latent cancer fatalities [LCFs]). The onsite and public radiological impacts range from 26 person-rem annually (or 0.01 LCFs) (ORNL) to 53 person-rem annually (or 0.03 LCFs) (INEL). For shipments to Nordion (see Appendix B), (100% demand), the calculated radiological impacts range from 21 person-rem (ORNL) to 23 person-rem (LANL and SNL/NM) to the combined crew; and from 33 person-rem (ORNL) to 69 person-rem (LANL and SNL/NM) to onsite individuals and the public. The calculated onsite and public health effects, range from 0.02 to 0.04 LCFs and to the combined crew are less than 0.01 LCFs.

This action may require the transport of highly enriched uranium to the target fabrication facilities. Currently, all of the sites (except for SNL/NM) have a sufficient supply of highly enriched uranium in

Table 5-9. Summary of Transportation Routing Information

Option/Material Transported		Shipments/yr	Shipment Description (km one-way) ^(a)	
Transportation Route			Onsite	Offsite
Origin	Destination			
Target Fabrication, Irradiation, Separations, and Waste Handling at LANL				
Unirradiated Targets				
CMR Facility	Omega West Reactor	52	6.5	0
Irradiated Targets				
Omega West Reactor	CMR Facility	52	6.5	0
Low-Level Waste				
CMR Facility	Technical Area 54 ^(b)	90	8	0
Separated Medical Isotope				
CMR Facility	Albuquerque Int Airport	1520	18	135
Albuquerque Int Airport	Boston, MA ^(c)	380	Not applicable	3200
Boston, MA	Dupont-Merck	380	Not applicable	56
Albuquerque Int Airport	Chicago, IL	380	Not applicable	1800
Chicago, IL	Amersham Medipysics	380	Not applicable	13
Albuquerque Int Airport	St. Louis, MO	380	Not applicable	2200
St. Louis, MO	Mallinckrodt Medical	380	Not applicable	8
Target Fabrication at LANL or SNL/NM; Irradiation and Separations at SNL/NM; and Waste Handling at Nevada Test Site				
Unirradiated Targets				
LANL-CMR Facility	ACRR	52	28	148
SNL/NM-Hot Cell Facility	ACRR	52	0	0
Irradiated Targets				
ACRR	Hot Cell Facility	52	0	0
Low-Level Waste				
Hot Cell Facility	NTS	90	9	1099
Separated Medical Isotope (Shipments from Albuquerque Int Airport to distributors as above)				
Hot Cell Facility	Albuquerque Int Airport	3225	9	8.5
Target Fabrication, Irradiation, and Separations at ORNL, and Waste Handling at NTS				
Unirradiated Targets				
Radioisotope Development Laboratory	ORRR	52	0	0
Irradiated Targets				
ORRR	Radioisotope Development Laboratory	52	0	0

Table 5.9. (contd)

Option/Material Transported		Shipments/yr	Shipment Description (km one-way) ^(a)	
Transportation Route			Onsite	Offsite
Origin	Destination			
Low-Level Waste				
Radioisotope Development Laboratory	NTS ^(b)	90	11	3300
Separated Medical Isotope (Shipments from Destination Airports to distributors as above)				
Radioisotope Development Laboratory	McGhee Tyson Airport	1520	11	29
McGhee Tyson Airport	Boston, MA ^(c)	380	Not Applicable	1340
McGhee Tyson Airport	Chicago, IL	380	Not Applicable	750
McGhee Tyson Airport	St. Louis, MO	380	Not Applicable	650
Target Fabrication, Irradiation, Separations, and Waste Handling at INEL				
Unirradiated Targets				
Test Area North Facility	Power Burst Facility Reactor	52	53	0
Irradiated Targets				
Power Burst Facility Reactor	Test Area North Facility	52	53	0
Low-Level Waste				
Test Area North Facility	ICPP ^(b)	90	44	0
Separated Medical Isotope (Shipments from Destination Airports to distributors as above)				
Test Area North Facility	Idaho Falls Airport	1520	80	40
Idaho Falls Airport	Boston, MA	380	Not Applicable	3320
Idaho Falls Airport	Chicago, IL	380	Not Applicable	1990
Idaho Falls Airport	St. Louis, Mo	380	Not Applicable	1890
(a) Zero onsite distance implies facilities are adjacent.				
(b) Assuming 52 target shipments/yr, 24 targets/shipment, and waste from 14 targets/waste cask.				
(c) Transportation impacts for shipments and number of shipments (380/yr) to Nordion are similar or bounded by the analyses.				
ACRR - Annular Core Research Reactor; CMR - Chemistry and Metallurgy Research Facility; ICPP-Idaho Chemical Processing Plant; ORRR - Oak Ridge Research Center; NTS - Nevada Test Site.				

storage to fabricate targets for five years or more. Consequently, no environmental impacts would be associated with transporting highly enriched uranium to these sites. For SNL/NM, approximately 25 kg of highly enriched uranium per year are estimated to be needed. The impacts of this were estimated, based on information presented in DOE 1995r. Preliminary unit risk values (person-rem/km per kg of highly enriched uranium shipped) were also derived from this data. Based on the results for the option in DOE (1995r) in which would be shipped from the Y-12 Area to Erwin, Tennessee for blending, the unit risk values were calculated to be 5×10^{-8} person-rem/km-kg for the public and 1.3×10^{-7} person-rem/km-kg for truck crews. These values were then multiplied by the approximate distance from Y-12 to SNL/NM (2200 km) and the annual highly enriched uranium requirements (25 kg/yr) to calculate the annual radiological exposures for the highly enriched uranium shipments needed by SNL/NM to fabricate the required targets. The resulting radiological exposures for incident-free transport were 3×10^{-3} person-rem/yr to the public and 7×10^{-3} person-rem/yr to the truck crews. These exposures are insignificant, relative to the annual exposures presented in Table 5-10.

Although not shown in Table 5-10, the radiological impacts for air transport activities account for greater than 90% of the totals. This percentage is primarily due to the number of air shipments required annually, the number of passengers and crew exposed during the entire flight, and the number of individuals exposed in the airport terminal. However, the calculated dose to an individual passenger is approximately 0.7 mrem/shipment, which is less than the average dose received by a passenger from

Table 5-10. Radiological Impacts Due to Routine or Incident-Free Transportation

Alternative	Radiological impacts (person-rem/yr) ^(a)		Health Effects (LCFs/yr) ^(d)	
	Crew ^(b)	Public ^(c)	Crew ^(b)	Public ^(c)
Los Alamos National Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	23 (1)	52 (0.08)	0.01	0.03
Los Alamos National Laboratory or Sandia National Laboratories Target Fabrication and Irradiation and Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	24 (2)	52 (0.2)	0.01	0.03
Oak Ridge National Laboratory, Target Fabrication, Irradiation and Separations, Waste to Nevada Test Site, and Shipments from McGhee Tyson Airport	23 (2)	26 (0.2)	0.01	0.01
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	23 (1)	53 (0.05)	0.01	0.03
(a) Radiological impacts for truck transport are shown in parentheses.				
(b) Truck crew and air transport crew, including handlers at hubs.				
(c) Includes public and onsite individuals where appropriate.				
(d) Latent cancer fatalities calculated in accordance with ICRP Publication 60 (ICRP 1991).				

natural cosmic radiation during a 4-hour flight (2 mrem) (NCRP 1987). This dose is also negligible relative to the annual dose received by the average U.S. citizen from natural and man-made radiation sources (approximately 360 mrem/yr) (NCRP 1987).

Assuming the medical isotopes are shipped air cargo, the crew impacts would remain approximately the same; however, impacts to the public (passengers and people in the airport terminal) would be significantly lower (less than 1 person-rem/yr).

5.11.2.2 Nonradiological Impacts from Transportation Activities

Impacts to the public from nonradiological causes were also evaluated. These impacts include fatalities resulting from pollutants emitted from the vehicles during normal transportation. Based on the information contained in Rao et al. (1982), the types of pollutants that are present and can impact the public are sulfur oxides (SO_x), particulates, nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons (HC), and photochemical oxidants (O_x). Of these pollutants, Rao et al. (1982) determined that the majority of the health effects are due to SO_x and the particulates. Unit risk factors (fatalities per kilometer) for truck shipments were developed by Rao et al. (1982) for travel in urban population zones ($1 \times 10^{-7}/\text{km}$ for truck).

Table 5-11 presents the results of the incident-free or routine nonradiological impacts. As shown in this table, the impacts to the public (not including onsite individuals) are essentially the same as the radiological impacts (0.008 to 0.009 fatalities).

Table 5-11. Nonradiological Impacts to the Public Due to Routine or Incident-Free Transportation

Alternative	Fatalities/yr
Los Alamos National Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	0.008
Los Alamos National Laboratory or Sandia National Laboratories Target Fabrication and Irradiation and Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	0.009
Oak Ridge National Laboratory, Target Fabrication, Irradiation and Separations, Waste to Nevada Test Site, and Shipments from McGhee Tyson Airport	0.009
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	0.008

5.11.3 Transportation Accident Impacts

Radiological and nonradiological transportation accident impacts during transportation of unirradiated and irradiated targets, separated isotopes, and secondary waste products for each of the alternatives are

discussed in the following subsections. A detailed description of the analysis methodology and accident characteristics is provided in Appendix B.

5.11.3.1 Radiological Impacts Due to Transportation Accidents

Radiological impacts are calculated for the public, as well as the MEI (located 100 m or 328 μ from the accident). The impacts to the public are presented in this section as integrated population risks (that is, accident frequencies multiplied by consequences integrated over route-specific population data, for a 1-year shipping campaign).

Population risk calculations were performed using the RADTRAN 4 computer code (Neuhauser and Kanipe 1992) (see Appendix B). The radiological doses to the MEI have been calculated using GENII (Napier et al. 1988). The results of the integrated population risk assessment presented in Appendix B are summarized in Table 5-12.

Table 5-12. Radiological Impacts Due to Transportation Accidents, Including Truck and Air Transport

Alternative	Public ^(a)	
	Radiological Risk (person-rem/yr) ^(b)	Health Effects Risk (LCFs) ^(c)
Los Alamos National Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	0.04 (5 x 10 ⁻⁴)	2 x 10 ⁻⁵
Los Alamos National Laboratory or Sandia National Laboratories Target Fabrication and Irradiation and Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	0.04 (2 x 10 ⁻³)	2 x 10 ⁻⁵
Oak Ridge National Laboratory, Target Fabrication, Irradiation and Separations, Waste to Nevada Test Site, and Shipments from McGhee Tyson Airport	0.02 (8 x 10 ⁻⁴)	1 x 10 ⁻⁵
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	0.04 (5 x 10 ⁻⁴)	2 x 10 ⁻⁵
(a) Includes public and onsite individuals where appropriate.		
(b) Radiological impacts for truck transport are shown in parentheses.		
(c) Latent cancer fatalities calculated in accordance with ICRP Publication 60 (ICRP 1991).		

The radiological impacts to the public (including onsite individuals) associated with truck transportation accidents range from 0.02 person-rem (ORNL alternative) to 0.04 person-rem (LANL and SNL/NM alternatives 100% demand). The projected health effects are less than 2x10⁻⁵ LCFs. For shipments to Nordion (see Appendix B), the calculated radiological impacts are 0.05 person-rem and the calculated health effects are 2 x 10⁻⁵ LCFs.

Results of Transportation Accident Impacts to a Maximally Exposed Individual. In addition to the radiological dose to the public, the doses to an MEI were calculated. It was assumed that a vehicle accident that would result in a release (catastrophic cask failure) would result in crew fatalities; therefore, radiological impacts to the crew were not calculated. The MEI was assumed to be located 100 m (328 ft) from the accident.

Radiological accident impacts to the MEI are calculated using GENII (Napier et al. 1988) (see Appendix B). To calculate the impacts to the receptor, it was assumed the release occurred at ground level due to catastrophic failure of a shipping cask.

The dose by material to the MEI located 100 m (328 ft) from a truck transportation accident is shown in Table 5-13. As can be seen, the dose received due to an accident involving a shipment of iodine-131 is greater than all other calculated doses

Table 5-13. Accidental Releases and Dose to the Maximally Exposed Individual Located 100 m (328 ft) from Transport Accident

Isotope/Material	Unirradiated Target	Irradiated Target	Mo-99	I-125	I-131	Xe-133	Waste
Qty. of Material ^(a)	1.1 x 10 ⁻³ Ci	one shipment	41.0 Ci	0.35 Ci	11.0 Ci	31.0 Ci	one shipment
Dose (rem)	0.91	1.3	0.62	0.054	2.6	0.063	1.4 x 10 ⁻⁶
(a) With the exception of the irradiated target and waste, quantities shown are the quantities respirable.							

5.11.3.2 Nonradiological Impacts from Transportation Accidents

This section summarizes the analyses presented in Appendix B to assess nonradiological impacts. Nonradiological accident impacts are the fatalities resulting from potential vehicular accidents involving the shipments. It is assumed that a vehicle accident that would result in a release from a shipping cask could also result in crew fatalities; therefore, nonradiological vehicular accident impacts are calculated for the public and transport crew.

The results of the nonradiological accident impact calculations for the four potential shipping scenarios are presented in Table 5-14. The values reported in the table represent the sum of the impacts from all of the shipments and include the impacts from shipments carrying cargo, as well as those from empty return shipments.

Table 5-14. Nonradiological Impacts Due to Truck Transportation Accidents

Alternative	Fatalities/ Year ^(a)
Los Alamos National Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	0.01
Los Alamos National Laboratory or Sandia National Laboratories Target Fabrication and Irradiation and Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	0.01
Oak Ridge National Laboratory, Target Fabrication, Irradiation and Separations, Waste to Savannah River Laboratory, and Shipments from McGhee Tyson Airport	0.02
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	0.01
(a) Includes public and transport crew.	

5.12 Occupational and Public Health and Safety

Implications of implementing the alternatives for production of medical isotopes on worker and public health and safety at the candidate sites are discussed in the following subsections. In general, this section summarizes material presented in Sections 5.7, 5.8, 5.11, and 5.15.

5.12.1 Radiological Consequences to Members of the Public

Emissions of radionuclides to surface- or groundwater would not be expected from normal operations in any alternative associated with production of medical isotopes. The majority of radiological consequences to the public result from air emissions associated with medical isotope production facilities (see Section 5.7) or from transportation of separated isotopes to distributors (see Section 5.11). Collective doses to the offsite populations within 80 km (50 mi) from facility air emissions could range from 0.6 to 15 person-rem/yr at the alternative sites (Section 5.7). Transportation was estimated to result in 49 to 76 person-rem/yr, primarily through direct exposure to workers and the public during air shipments (Section 5.11). The affected populations for transportation would be different from those surrounding the production sites. Neither facility operations nor transportation would be expected to result in latent cancer fatalities for a year of isotope production operations, or for any reasonable duration of the project.

Radionuclide emissions to air from processing irradiated targets might result in doses to the maximally exposed offsite individual of 0.004 to 0.3 mrem/yr, depending on the site selected. Estimated doses from operation of the reactors during target irradiation were generally lower than those for target processing, amounting to 0.0002 to 0.2 mrem/yr. Target fabrication would not be expected to add measurably to radionuclide air emissions.

The U.S. Environmental Protection Agency (EPA) radionuclide air emission standards for DOE facilities limit the dose to a member of the public to 10 mrem/yr for the air pathway (as calculated using the EPA Clean Air Act Assessment Package 1988 [CAP88] model, which generally results in doses similar to those from the GENII code used in this analysis). Doses to individual members of the public from all pathways (including air, water, and direct exposure) are limited by DOE regulations to 100 mrem/yr. This limit would apply to individual transportation workers who are involved in commercial air shipments, and who are assumed, for the purpose of this analysis, to be members of the public. The activities evaluated in this EIS would comply with EPA and DOE regulations for radiation exposure to the public.

For perspective, an average person in the U.S. receives about 300 mrem (0.3 rem) per year from natural background sources of radiation and an additional 60 mrem/yr from artificial sources, such as medical exposure (NCRP 1987). The collective annual dose from natural background radiation to populations within 80 km (50 mi) of the DOE sites considered in the FEIS alternatives would therefore amount to approximately 180,000 person-rem at SNL/NM (610,000 people), 75,000 person-rem at LANL (250,000 people), 270,000 person-rem at the Oak Ridge Reservation (910,000 people), and 36,000 person-rem at INEL (120,000 people).

Accidental releases of radionuclides during transportation or facility operation have the potential to result in health effects if the accidents occur (see Sections 5.11 and 5.15). However, the risk from such accidents, accounting for accident frequency as well as consequences, is sufficiently low that no health effects would be expected for any of the alternatives considered in this FEIS.

5.12.2 Radiological Consequences to Workers

Direct radiological exposures to workers during routine facility operations are summarized in Table 5-15. Collective worker doses might vary somewhat from site to site because of facility-specific considerations; however, because the processes are similar at all sites, the doses to involved workers would likely be within the range of doses estimated for the SNL/NM and LANL operations (Massey et al. 1995). Annual worker doses during facility modifications would likely be bounded by the annual operational dose estimates because the quantities of radioactive materials that might be encountered during the minor construction projects would be substantially lower than during operations for these facilities, which are not highly contaminated. For example, estimates of the worker dose for refueling and replacing instrumentation at the Power Burst Facility were about 8 person-rem, and LANL estimates for hot cell decontamination were about 2.5 person-rem. Doses from air emissions to onsite workers outside the facility are likewise expected to be lower than those to workers directly involved in the isotope production operations.

Table 5-15. Routine Radiological Exposures to Workers During Facility Operations (Massey et al. 1995)

Operation	Collective Worker Dose (person-rem/yr)			
	SNL/NM	LANL	ORNL	INEL
Target Fabrication	0.5	0.5	(a)	(a)
Reactor Operation	10.0	5.0	(a)	(a)
Target Processing	9.0	1.5	(a)	(a)
Onsite Loading of Isotope Shipments	2-5	2-5	(a)	(a)
Total	22-25	9-12	(a)	(a)
Latent Cancer Fatalities	0.009-0.01/yr	0.004-0.005/yr	(a)	(a)
(a) Dose estimates for these sites are expected to fall within the range of those for SNL/NM and LANL.				

Collective worker doses of the magnitude estimated for isotope production would not be expected to result in latent fatal cancers for any reasonable duration of the project (0.004 to 0.01 per year of operation).

Individual doses for workers at DOE facilities are limited to 5 rem/yr by regulation, and at many DOE facilities, they are controlled administratively to a maximum of 0.5 rem/yr, unless special approval is obtained. DOE facilities are required to implement programs that will maintain worker doses as low as reasonably achievable by evaluating processes where radioactive materials are handled and using procedures to minimize worker exposure wherever possible. For most types of operations, individual worker doses would be well below the applicable administrative control levels.

Impacts to individual involved workers from radiological accidents at facilities associated with medical isotope production were estimated to result in doses of 1 to 80 rem (Massey et al. 1995). Doses of that magnitude have the potential to produce short-term effects on the individuals involved but would not be considered life-threatening with appropriate medical management.

5.12.3 Nonradiological Consequences

The consequences of routine emissions to air and water of nonradiological compounds that could result in potential health effects are discussed in Sections 5.7, 5.8, and 5.11. Emissions of criteria pollutants (particulates, nitrogen oxides, and sulfur oxides) from facilities or vehicles during modification or transportation would not be expected to result in adverse health effects at these levels (Section 5.11). Routine emissions of other potentially hazardous materials to air or water are not expected as a result of any alternatives in this EIS.

Accidents involving releases of hazardous or toxic material from facilities are evaluated in Section 5.15, and potentially could result in adverse health effects to a limited number of nearby individuals if such accidents were to occur. Because the accident assessment uses hypothetical, nonspecific release scenarios based on facility inventory, the estimated frequency and the resulting risk from these accidents cannot be assessed directly. However, the frequencies of the types of accidents that could result in substantial releases to the environment are typically low enough that they would not be expected to occur during the operations considered in this EIS.

Health effects and fatalities due to traffic or industrial accidents are discussed in Sections 5.11 and 5.15, respectively. Facility modification would be expected to contribute to, at the most, seven illnesses or injuries over the time required to modify facilities for medical isotope production, and two or less per year during normal operations, based on historical operating statistics for DOE facilities (see Section 5.15). Traffic accidents, and accidents during facility modification and operation, would not be expected to result in any fatalities during a year of normal operations.

5.13 Site Services and Resources

5.13.1 Annular Core Research Reactor: Sandia National Laboratories/New Mexico and the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

This section provides a discussion on the use of materials, energy, and chemicals associated with upgrading or operation of the facilities necessary to produce Mo-99 at SNL/NM and SNL/LANL. Plans remain in the conceptual stage, and detailed designs have not yet been prepared.

5.13.1.1 Modifications at LANL for Target Fabrication

Several upgrades would be required at the LANL target fabrication facility, all of which would require energy and materials:

- Nine glove boxes would be custom fabricated to contain the apparatus for target fabrication in two duplicate production lines. Each glove box exhaust would be fitted with a HEPA filter. Apparatus in glove boxes would include dissolution tanks, introduction boxes, and target coating equipment. Exhaust ducting and fans would connect the glove box ventilation systems to the existing Chemistry and Metallurgy Research Facility, Wing 9 ventilation system.
- Some interior walls would be removed and doors would be relocated.

5.13.1.2 Modifications at SNL/NM Hot Cell Facilities

If target fabrication is to be performed at SNL/NM, certain modifications would be required. Upgrades and improvements required for SNL/NM target fabrication facilities would be essentially the same as those required for the LANL facilities, as described in Section 5.13.1.1.

5.13.1.3 Annular Core Research Reactor Facility Modifications at SNL/NM

Several upgrades would be required at the Annular Core Research Reactor, all of which would require energy and materials. In addition, the reactor would need to operate on a sustained basis. Materials and energy expended to accomplish the proposed upgrades, as described in Section 3.0, are estimated in Table 5-16.

5.13.1.4 Hot Cell Facility Modifications

Several upgrades would be required at the hot cell facility, as described in Section 3.0, all of which would require energy and materials. Table 5-16 provides estimated resource use.

Table 5-16. Estimated Annual Quantities of Selected Resources Required for 100% Operation and Upgrade of Facilities at Each Site.

Site	Resources Required for Construction				Annual Resources Required for Operations				
	Concrete m ³ (yd ³)	Steel tonnes (tons) ^(a)	Electricity (kWh) ^(b)	Stainless Steel tonnes (tons)	Water (evap cooling) m ³ /yr (gal/yr)	Electricity (Mwh)	LEU (fuel bundle total) kg (lb)	HEU (U ²³⁵ targets) kg (lb)	Targets Stainless Steel tonnes (tons)
SNL	1200 (1500)	0.21 (0.24)	230	1.0 (1.1)	40,000 (11 x 10 ⁶) ^(c)	400	16 (35)	4-36 (8-79) ^(d)	0.50 (1.1)
LANL	0	0	negligible	0.2 (0.22)	120,000 (31 x 10 ⁶)	500	32 (70)	3 (7) ^(d)	0.36 (0.8)
ORNL	20 (26)	negligible	4	3.5 (3.9)	120,000 (31 x 10 ⁶)	500	32 (70)	3-26 (7-57) ^(d)	0.36 (0.8)
INEL	2400 (3100)	0.39 (0.44)	450	1.5 (1.7)	120,000 (31 x 10 ⁶)	500	32 (70)	3-26 (7-57) ^(d)	0.36 (0.8)

Notes:

(a) Numbers were derived by proportion from data acquired from other DOE construction projects. An assumption was made that the amount of steel required per cubic yard of concrete poured would be similar for hot cell walls and spent nuclear fuel storage facilities.

(b) Numbers were derived by proportion from data acquired from other DOE construction projects. An assumption was made that the amount of electricity consumed per cubic yard of concrete poured would be similar for constructing spent nuclear fueled storage facilities and for constructing hot cell facilities.

(c) From: DOE 1994e.

(d) Minimum values assume approximately 90% U-235 recovery. Recovery would occur at LANL, and could be implemented at other sites. However, the analyses presented in other sections do not assume uranium recovery at sites other than LANL.

5.13.1.5 Operational Resources Required

Target fabrication would require resources, the most important of which would be highly enriched (93%) uranium-235 and stainless steel. Table 5-16 provides an estimate of these resource needs.

- Stainless steel for target fabrication. A typical target would be constructed of stainless steel tubing approximately 0.89 mm (0.035 in.) thick, 46 cm (18 in.) long, and 3.2 cm (1.25 in.) in diameter.
- Highly enriched uranium is coated onto the stainless steel targets for irradiation in the reactors.

Electrical use for operation of the reactor is anticipated to be approximately 400 MWh/yr. Yearly water consumption is estimated to be 40,000 m³ (11 x 10⁶ gal).

In addition, the chemical use anticipated for target processing to produce Mo-99 is shown in Table 5-17.

Table 5-17. Approximate Yearly Chemical Usage for Production of Molybdenum-99 at Any of the Proposed Project Sites

Chemical Identification	Annual Consumption ^(a)
sulfuric acid, 2N	120 L
sulfuric acid, 0.1N	36 L
hydrochloric acid, reagent grade	1.2 L
nitric acid, reagent grade	6 L
sodium hydroxide, 0.2N	24 L
sodium iodide	120 g
silver nitrate	600 g
benzoin-a-oxime	2.4 Kg
molybdenum trioxide	24 g
potassium permanganate	100 g
rhodium trichloride	24 g
potassium hexachlororuthenate	24 g
hydrogen peroxide	2.4 L
calcium oxide	12 L
calcium sulfate (drierite)	36 L
calcium sieve type 13X	36 L
(a) From (DOE 1994b). Values are based on 100% replacement of U.S. requirements using 20 kW targets. At SNL/NM, the requirements would increase by about 40% because a greater number of targets would be required to achieve 100% replacement of U.S. demand.	

5.13.2 Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

This section provides a discussion on the use of materials, energy, and chemicals associated with upgrading or operation of the facilities necessary to produce Mo-99 at the Omega West Reactor at LANL.

5.13.2.1 Materials Required for Omega West Reactor Upgrades

Resource consumption data on materials, energy, and chemicals required to upgrade the Omega West Reactor to produce Mo-99 have been estimated (Table 5-16). Plans are in the conceptual stage, and detailed designs have not yet been prepared.

5.13.2.2 Operational Resources Required

Electrical consumption for operation is estimated to be 500 MWh/yr. Yearly water consumption for evaporative cooling is estimated to be 120,000 m³ (31 x 10⁶ gal) per year. Requirements for target fabrication and processing would be as described in Section 5.13.1.5.

5.13.3 Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory Alternative

This section discusses the use of materials, energy, and chemicals associated with retrofitting or operating the facilities necessary to produce Mo-99. Anticipated upgrades include activities needed to restart the reactor, relocate cooling towers, and install process equipment in the hot cells. Plans are in the conceptual stage, and detailed designs have not yet been prepared. Table 5-16 provides estimated resource use for facility upgrades and operations.

5.13.3.1 Oak Ridge Research Reactor Facility Modifications

Several upgrades would be required at the Oak Ridge Research Reactor facility, as described in Section 3.0, all of which would require energy and materials. The major material requirement is an estimated 20 m³ (26 yd³) of concrete for relocating the cooling towers (Table 5-16).

5.13.3.2 Mo-99 Processing Facility Modifications

Several upgrades would also be required at the target fabrication and Mo-99 processing facility, as described in Section 3.0, all of which would require in energy and materials. Estimated quantities of materials and energy necessary to accomplish these upgrades are listed in Table 5-16.

5.13.3.3 Operational Resources Required

It is estimated that the Oak Ridge Research Reactor would consume 500 MWh/yr of electrical power and 120,000 m³ (3.1×10^7 gal) per year of water for evaporative cooling (Table 5-16). Requirements for target fabrication and processing would be as described in Section 5.13.1.5.

5.13.4 Power Burst Facility/Test Area North: Idaho National Engineering Laboratory Alternative

This section provides a discussion on the use of materials, energy, and chemicals associated with retrofitting or operating the facilities necessary to produce Mo-99. Plans are in the conceptual stage, and detailed designs have not yet been prepared.

5.13.4.1 Power Burst Facility Modifications

The Power Burst Facility would require a few modifications to be able to restart. A significant portion of the reactor instrumentation would need to be replaced and all of the systems would need to be tested to determine operability. Data on exact quantities of materials and energy necessary to accomplish these upgrades are not available.

5.13.4.2 Hot Cell Facility Modifications

The existing Test Area North hot cell annex would require slight modifications to be able to receive and process the target elements, as described in Section 3.0. Data are not available on exact quantities of materials and energy expended to accomplish the proposed upgrades and for processing of irradiated targets.

If new hot cells are constructed adjacent to the Power Burst Facility, instead of using existing facilities, it is estimated that 2400 m³ (3100 yd³) of concrete and one half ton of steel would be needed.

5.13.4.3 Operational Resources Required

It is estimated that the Power Burst Facility would consume 500 MWh/yr of electrical power and 120,000 m³/yr (31×10^6 gal/yr) of water use for evaporative cooling (Table 5-16), based on anticipated operating power levels. Requirements for target fabrication and processing would be as described in Section 5.13.1.5.

5.14 Waste and Spent Nuclear Fuel Management

The Cintichem process would be used under each of the alternatives. A detailed description of the Cintichem process can be found in Appendix A. The purpose of this section is to identify wastes generated by that process, how these wastes could be handled, and what impact they may have on current site waste management capabilities. An evaluation of that information is included under the discussion of the preferred alternative of SNL/LANL. Significant variations in waste volume production and management issues are addressed in the subsequent alternative sections (5.14.2 through 5.14.4). For each alternative, the wastes generated would be required to meet applicable waste acceptance criteria to ensure that wastes are safely treated and disposed.

Management of spent nuclear fuel is also considered for each of the alternatives. Near-term management of spent fuel would occur at the site where the fuel was initially generated. All of the sites have the capacity to store the limited quantities of spent nuclear fuel resulting from Mo-99 production for at least 5 years, assuming 100% production. The facilities identified for spent nuclear fuel storage in this FEIS were evaluated in a 1993 DOE report (DOE 1993d). Although some of the spent nuclear fuel storage facilities identified in this FEIS were listed as having vulnerabilities, none of those vulnerabilities were identified as priority issues needing immediate corrective action. All corrective actions necessary to allow the safe storage of spent nuclear fuel generated during Mo-99 production would be completed prior to storage of fuel in the affected facilities.

The DOE intends to produce a baseline quantity of Mo-99 (about 10% to 30% of U.S. demand) in order to maintain the capability to respond to shortages in domestic Mo-99 supply. Because the DOE intends to produce Mo-99 even when the Canadian source is supplying Mo-99, periods may occur when the DOE is unable to sell the Mo-99 that it produces. In this case, the unsold Mo-99 would be disposed of as low-level radioactive waste at the same disposal site as other low-level wastes generated during Mo-99 production. The disposal of unsold Mo-99 with the other low-level radioactive waste generated during production is bounded by the analyses in this section.

5.14.1 Annular Core Research Reactor: Sandia National Laboratories/New Mexico and Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

5.14.1.1 Waste Generation from Medical Isotope Production

The Mo-99 process and the waste produced can be divided into three major stages: target fabrication, reactor irradiation of the uranium-loaded targets, and processing (recovery) where molybdenum is chemically extracted from the other fission products in a hot cell facility. Waste quantities in this analysis are based on production rates required to supply 100% of U.S. needs.

Target Fabrication. Target fabrication would be done at the Chemistry and Metallurgy Research Facility at LANL. Target fabrication would be performed inside glove boxes where 93%-enriched uranium would be coated on the inner walls of stainless steel tubes. Spent plating solution would be recycled in the ion exchange glove boxes to recover unused uranium. LANL is the only alternative (of the four sites under consideration) with the pre-existing capability to perform this recycle step. Residues consisting of low activity, low-level waste, would be collected in holding tanks, sampled, and analyzed before being transported through a process line to the TA-50 Radioactive Liquid Waste Treatment Facility onsite at LANL. Approximately 7.3 m³/yr (140 L/wk) of low-level solidified liquid waste would result from the target fabrication process. Alternatively, the residue solution could be placed in interim liquid waste storage tanks, then routed later to the TA-50 Low-Level Liquid Waste facility. Some solid low-level waste, (gloves, lab equipment), approximately 7.0 m³ (247.0 ft³), would be produced annually. This low-level solid waste would be routed to the Area G, TA-54 facility. No hazardous or mixed waste would be produced (Massey et al. 1995).

Target Irradiation. Target irradiation would occur at the Annular Core Research Reactor at SNL/NM and continue for about 7 days. The irradiation process is expected to produce 57 spent fuel elements (16 kg [35.2 lb] of uranium) a year under full production power of approximately 3 MW. Each element would be approximately 1.5 kg (3.3 lb) total mass. The spent fuel elements would consist only of solids; no liquids would be present.

SNL/NM would have sufficient storage space for the spent nuclear fuel in the adjacent Gamma Irradiation Facility (GIF) pool. The GIF pool is capable of storing 300 fuel elements. At the anticipated rate of discharge, the GIF pool would be adequate for up to 5 years of near-term storage. Additional racks could be added to extend the storage capacity to 1000 elements, or up to 17 years, if required. The fuel elements could also be moved, after an initial cooling period of approximately 1 year, into dry spent nuclear fuel storage located in the same area. If dry storage is desired, the spent nuclear fuel would be removed from the pool and placed in storage casks. These casks would be monitored to verify the integrity of the spent nuclear fuel and the casks.

Permanent storage of spent nuclear fuel from all sites would be in accord with a future DOE decision on its ultimate disposition. DOE has completed a programmatic FEIS that addresses the potential environmental consequences over the next 40 years of the alternatives related to the transportation, receipt, processing, and storage of DOE spent nuclear fuel.

The Record of Decision for the SNF PEIS (DOE 1995b) provides for interim storage of all DOE-managed spent nuclear fuel at one of three designated DOE regional SNF management sites (INEL, Savannah River, or Hanford) for up to 40 years or until a decision has been made on its ultimate disposition. Under this decision, research reactor fuel from the Annular Core Research Reactor would be shipped offsite for management at INEL, the regional site designated by DOE for interim management of its stainless steel clad spent fuel.

Processing. Mo-99 is generated as a fission product in the targets. After irradiation of the target, processing (recovery/extraction) occurs in dedicated, shielded confinement boxes where the molybdenum is extracted from the remainder of the fission products by chemical dissolution and precipitation. Processing consists of several substeps including the removal of fission gases by condensation into a trap; addition of an acid solution to dissolve the plated uranium oxide coating; the separation and purification of Mo-99; and the collection and packaging of wastes.

Two types of waste products would be generated during processing: high-activity, low-level liquid waste; and hardware, such as glassware and tubing. Prior to packaging in drums, liquid waste would be solidified in metal containers. The estimated activity levels for the solidified liquid waste, from a single 10-kW target, are 4000 Ci after 1 day and 40 Ci after 6 months. The solidified liquid waste would be packaged in drums and stored separately from the remaining solid waste (glass, plastic, metals). Hardware would be compacted prior to packaging in drums. Solid waste has an estimated activity level of 5.3 Ci after 1 day and 2.5 Ci after 6 months (Massey et al. 1995).

Hot cell operations are expected to generate approximately 28 m³ (134 drums) of uncompactable waste, consisting mostly of targets and solidified liquid waste; and 56 m³ of compactable waste (14 m³, 67 drums, after compaction) consisting mostly of hardware. The total volume of low-level waste generated during processing would be approximately 42 m³ per year at 100% production (based on 27 targets per week). Hot cell operations are expected to generate approximately three to four 55-gal drums of low-level waste per week, or about 200 drums per year if SNL/NM supplied 100% of the U.S. need for Mo-99.

Waste drums would be stored temporarily in the hot cell itself for about 6 months to a year to reduce the activity level and allow for easier handling. At that time, the waste material would be shipped to the Nevada Test Site for final disposal. Drums could remain in the Hot Cell Facility for longer periods before disposal if necessary. One to two years of temporary storage is available at the Hot Cell Facility for projected operating wastes.

No mixed waste is expected to be generated in the recovery/extraction process; however, some incidental mixed waste, estimated to be less than 0.1 m³/yr under any of the alternatives, would be produced by facility operations incidental to the process. Examples of incidental mixed waste include absorbent wipes, batteries, spent solvents, lubricants, vacuum pumps, and other items that become contaminated with radioactive materials. These mixed waste streams would be managed in accordance with applicable requirements (Massey et al. 1995).

A summary of the types and masses of wastes produced from 12 targets (one drum) is given in Table 5-18. A generic flow chart illustrating the three primary processing steps in Mo-99 medical isotope production, the waste generated from each step, and the management of these wastes is provided in Figure 5-1. Although the quantity and type of waste produced from the processing step would be very similar for each alternative site, the final volumes would differ due to how and if the waste is treated, solidified, compacted, or crushed.

Table 5-18. Waste Characterization Data Summary^(a)

Waste Component	Mass/Target in grams	Mass/Drum in grams
Copper	1440	17,150
Stainless Steel	1380	16,550
Brass	18	220
Tin	290	3480
Aluminum	1	12
Glass	2770	33,260
Plastic	390	4630
Dry Chemicals	430	5170
Liquid Chemicals	670	8060
Cement	2430	29,120
Fission Products ^(b)	0.1	1.2
Total Mass	9800	117,640
Total Curies	53.9	646
(a) Data taken from LANL 1993e.		
(b) Includes Ba-137m, Ba-140, Ce-141, Ce-144, Cs-137, I-129, I-132, La-140, Nb-95, Nb-95m, Nd-147, Pm-147, Pr-143, Pr-144, Pr-144m, Rh-103m, Rh-106, Ru-103, Ru-106, Sm-147, Sr-89, Sr-90, Te-127, Te-127m, Te-129, Te-129m, Te-132, Y-90, Y-91, Zr-95.		

5.14.1.2 Waste Disposal

Low-level radioactive wastes would be shipped from SNL/NM to the Nevada Test Site for disposal. A site-wide EIS, currently being prepared by DOE for the Nevada Test Site, will address the consequences of the Mo-99 waste stream. Individual waste streams from SNL/NM must meet the waste acceptance criteria for the Nevada Test Site. Throughout the process, waste minimization would be implemented to the extent possible in keeping with good and safe laboratory practices.

5.14.1.3 Target Fabrication/Annular Core Research Reactor Irradiation: Sandia National Laboratories/New Mexico Alternative

As an alternative, the target fabrication process could be implemented at SNL/NM as opposed to LANL. Such a configuration would allow for all three Mo-99 processing stages to occur at the same site. The target fabrication process and low-level waste volumes would be the same as those developed by LANL and described previously in this section. Targets would be fabricated and stored onsite until needed

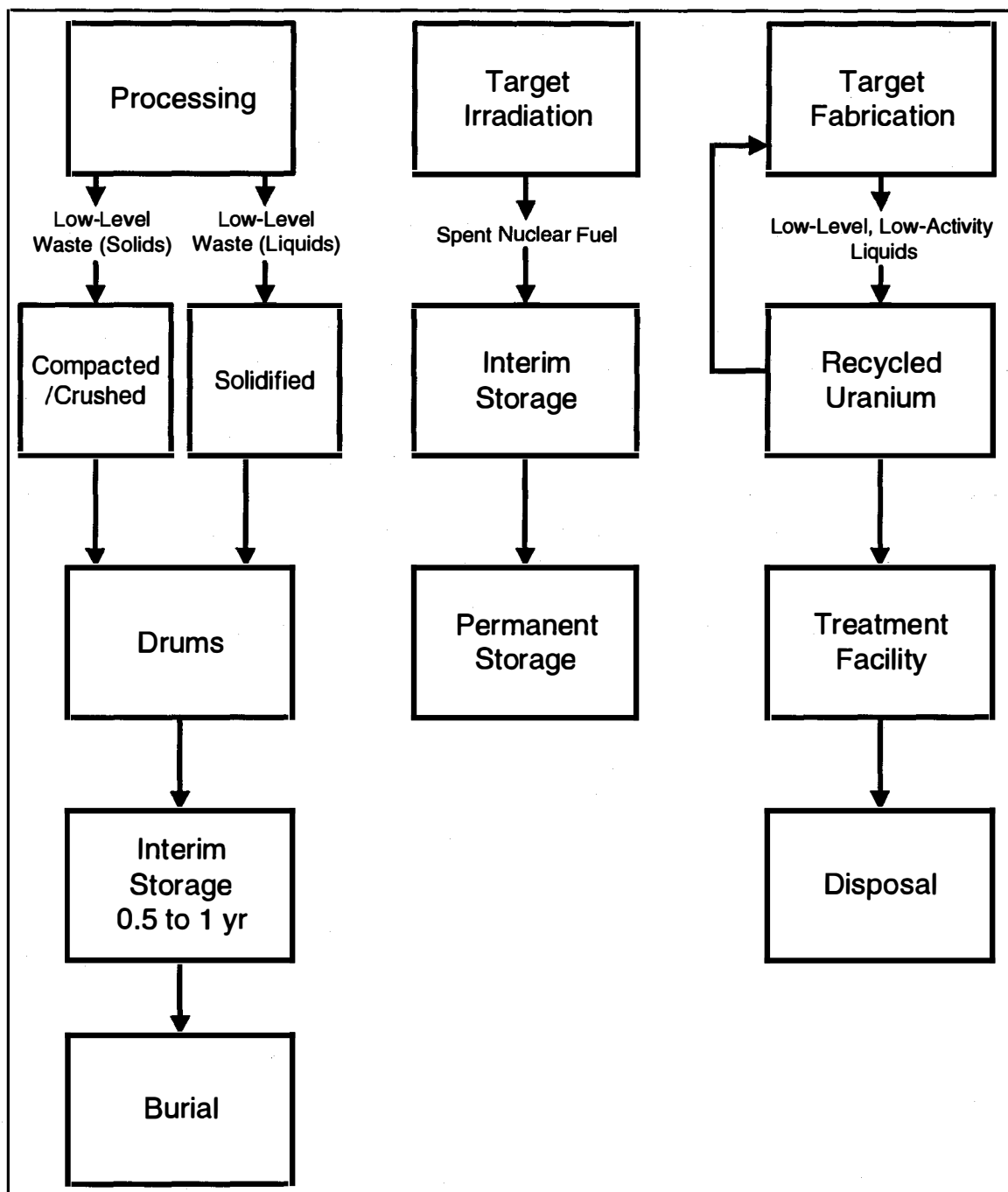


Figure 5-1. Waste Generation and Management. This figure is a generic representation of the Mo-99 production process. Specific variations on such steps as recycling, solidification compaction, and crushing are discussed in Subsection 5.14.1.1.

for irradiation in the Annular Core Research Reactor. The wastes (solid and liquid) from the fabrication process would be low-activity, low-level waste and would be transported to the Nevada Test Site for disposal along with the other low-level waste produced at SNL/NM. Unlike residue at LANL, the SNL/NM residue from the fabrication process would contain a greater concentration of uranium, because no uranium recycling step is in place.

5.14.2 Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

In this alternative, all three steps would be carried out onsite at LANL. The Chemistry and Metallurgy Research building would be used for manufacturing the targets (see Section 5.14.1.1) and recovering Mo-99 in the hot cells. Approximately 5.2 m^3 (183.7 ft^3) per year of low-level liquid waste and 5.0 m^3 (176.6 ft^3) per year of low-level solid waste would result from target fabrication. Target irradiation would take place at the Omega West Reactor, which would be repaired and restarted. At present, enough fuel elements are stockpiled to operate the reactor for several years. Approximately 16 targets per week would be irradiated at Omega West Reactor under current core configurations. After irradiation, the targets would be transferred to the Chemistry and Metallurgy Research Facility, Wing 9 Hot Cells for processing.

Spent fuel from the reactor, after a cooling-off period of about 6 months in the Omega West Reactor, would be transported in an existing container to the onsite storage area. Interim wet storage capabilities exist at the Omega West Reactor. Dry storage is also available at other facilities, including TA-54. At the anticipated discharge rate, LANL has adequate near-term spent nuclear fuel storage for up to 37 years. At full power, approximately 29 spent fuel elements (32 kg [70.5 lb] of uranium) per year would be discharged. In accordance with the Record of Decision for the SNF PEIS (DOE 1995b), spent fuel from the Omega West Reactor would be shipped offsite for management at the Savannah River Site, the regional site designated by DOE for interim management of its aluminum clad spent fuel. Under normal operating conditions, radioactive liquid wastes from Omega West Reactor are minimal. Wastes produced during irradiation are placed in drums for disposal under standard LANL low-level liquid waste disposal practices. Less than 2 L (0.53 gal) per year of liquid waste would be sent to the TA-50 radioactive liquid waste treatment facility for disposal.

Adequate facilities and space exist at LANL to handle, manage, and store all types of wastes, including spent fuel, generated during the Mo-99 production. Chemistry and Metallurgy Research Facility waste from processing would be collected or transferred via a radioactive liquid waste pipeline, and placed in labeled drums. Waste disposal from processing is predicted to entail weekly disposal of one or two 55-gal drums of waste or about 60 drums per year at 100% production. Liquid radioactive wastes would be stored for 3 months to allow for decay of short-lived radionuclides before being solidified and sent to TA-50; solid and incidental mixed wastes ($<0.1 \text{ m}^3$ [$<3.5 \text{ ft}^3$]) would be taken to TA-54, where the waste would be neutralized. LANL would crush its solid waste, thus reducing the volume presented for disposition from

the processing step. All waste management activities would be performed in accordance with the site's ongoing, innovative, waste minimization program. The total volume of low-level crushed waste (solidified liquid and solid) from processing would be approximately 12.6 m³ (16.5 yd³) per year. Incidental mixed waste would be less than 0.1 m³ (3.5 ft³).

5.14.3 Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory Alternative

The ORNL alternative would use the Oak Ridge Research Reactor, which would be restarted as a class B reactor and redesignated as the Medical Isotope Production Center. The Radioisotope Development Laboratory would be customized and dedicated for Mo-99 processing. A separate area in the Radioisotope Development Laboratory would be set up for fabrication. The target fabrication process and low-level waste volumes are expected to be the same as for LANL. No uranium recycling would occur at this time. Liquid and solid low-level waste from the fabrication process would be transported to the Nevada Test Site for disposal. As with the LANL alternative, all steps of Mo-99 production would occur at a single site.

The Oak Ridge Research Reactor has some capacity to handle spent nuclear fuel onsite. It has a storage pool capacity of 180 fuel elements, of which 96 would be used for core loading and 84 for storing spent fuel. At the anticipated rate of discharge of 22 spent fuel elements (32 kg [70.5 lb] of uranium) per year, the pool would be adequate for 4 years of operation. Additional storage space for approximately 900 Oak Ridge Research Reactor fuel elements is available at the nearby Bulk Shielding Reactor pool. This translates into approximately 40 years of additional spent nuclear fuel storage space. Less than 0.07% of DOE's spent nuclear fuel is either in storage or being generated at ORNL facilities (DOE 1995b). In accordance with the Record of Decision for the SNF PEIS (DOE 1995b), spent fuel from the Oak Ridge Research Reactor would be shipped offsite for management at the Savannah River Site, the regional site designated by DOE for interim management for its aluminum clad spent nuclear fuel.

Radioactive waste from target processing would be stored in the hot cell facility for approximately 6 months to allow the high activity, low-level waste to decay. The low-level waste would then be solidified, packed, and transferred to an above-ground pad for storage awaiting shipment to the Nevada Test Site. The anticipated total volume of low-level waste (solidified-liquid and solid) from processing would be approximately 63 m³ (82.4 yd³) per year. Oak Ridge does not currently have the capability to reduce this waste volume by compaction or compression. If ORNL supplied 100% of the U.S. need for Mo-99, processing operations are expected to generate approximately five to six drums of low-level waste per week, or about 303 drums per year. Resource Conservation Recovery Act (RCRA) mixed waste (incidental) (<0.1 m³/yr [<3.5 ft³/yr]) would be stored in permitted mixed waste areas, using the appropriate shielded or unshielded B-25 boxes, based on activity levels as previously discussed.

A detailed estimate of waste quantities and types would be developed after a specific engineering design is completed. All wastes would be managed in accordance with applicable requirements.

5.14.4 Power Burst Facility/Test Area North: Idaho National Engineering Laboratory Alternative

In this alternative, all three steps (fabrication, irradiation, and processing) would be carried out onsite at INEL. This alternative would use the Power Burst Facility for irradiating targets. Specific information for INEL regarding waste quantity and management for this proposed alternative is not yet available. The process and associated wastes (low-level waste, spent nuclear fuel, and $<0.1 \text{ m}^3$ [$<3.5 \text{ ft}^3$] of incidental mixed waste) would be very similar to those of the other proposed alternatives. The target fabrication process would generate approximately 5.2 m^3 (183.7 ft^3) of liquid low-level waste that would be treated and disposed of onsite. In addition, approximately 5.0 m^3 (176.6 ft^3) of solid low-level waste would be generated during target fabrication. During target irradiation, an anticipated discharge rate of 17 spent fuel elements (32 kg [70.5 lb] of uranium) per year is also expected. Processing would generate approximately 77.0 m^3 (104 yd^3) of combined liquid and solid low-level waste. After an initial 6-month cooling period at the Power Burst Facility, the spent nuclear fuel would be transferred to another onsite facility at the Idaho Chemical Processing Plant for interim wet or dry storage. It would likely be stored at the Irradiated Fuel Storage Facility (786 bundle capacity, if dry storage is selected); however, other facilities such as the CPP-666 (wet storage) or CPP-749 (dry storage) are also available. At the anticipated discharge rate, INEL has adequate near-term spent nuclear fuel storage for up to 46 years.

INEL has substantial hot cell and processing capabilities. Adequate facilities and space exist at INEL to handle, manage, and store all the types of waste generated during Mo-99 production. INEL is a cradle-to-grave waste management operation with all Mo-99 generated waste being managed within INEL facilities.

In accordance with the Record of Decision for the SNF PEIS (DOE 1995b), spent fuel from the Power Burst Facility would be managed at INEL as the regional site designated by DOE for interim management of its stainless steel clad fuel. INEL has been safely managing spent nuclear fuel for over 40 years. Currently, the site stores about 10% of DOE's spent nuclear fuel from a variety of DOE programs and a limited number of commercial and foreign sources (DOE 1995b).

Waste volumes associated with the processing of Mo-99 would not present significant increases in either solid or liquid waste volumes, compared with other typical INEL radioactive waste streams. All waste would be managed, stored, and eventually disposed of in accordance with applicable regulations and requirements.

5.14.5 Comparison to Current Waste Generation Rates

The volumes of spent nuclear fuel, low-level, and incidental mixed waste are summarized in Table 5-19 for each proposed alternative site. Waste generation quantities from the proposed Mo-99 production process are presented in comparison with current production volumes. No alternative is expected to generate high-level or transuranic waste.

5.15 Facility Accidents

Consequences of facility accidents associated with implementing the alternatives for medical isotope production are discussed in the following subsections. The method used to select accidents for analysis is described, as are the procedures for evaluating the consequences of selected accidents, and the results of the analysis.

The alternatives for medical isotope production considered in this FEIS necessitate evaluation of accidents at three different types of facilities. The facilities necessary to carry out the project include facilities for production of targets containing highly enriched uranium, irradiation of the targets in a reactor, transfer to the hot cell, and processing of targets to extract the medically useful isotopes. Hot cell facilities are typically used for the target fabrication and processing steps, and the irradiation, as proposed, would be carried out in a DOE research reactor at one of the candidate sites. The hot cell facilities for target fabrication and processing may be in the same location at the sites under consideration, but those activities would not necessarily have to occur at the same site.

Accidents evaluated for medical isotope production consist of maximum reasonably foreseeable accidents described in such previously published analyses as National Environmental Policy Act (NEPA) documentation, safety analyses, or are adaptations of accident scenarios developed for similar types of facilities. Source documents evaluated accidents caused by natural phenomena, mechanical, and procedural errors. These evaluations were considered when choosing the appropriate scenarios for consideration in the FEIS. Those accidents that had low probability, but high consequences were compared against those with higher probability and lower consequences. Thus, scenarios representing the greatest overall risk were chosen based on the product of the probabilities and the consequences for each accident type. Where applicable, the source documents for specific accidents evaluated in this section are referenced in the detailed accident descriptions. In some cases, the source documents predate the new DOE safety analysis order, and may not conform to current requirements. However, in all cases the source documents represent the best available information. With one exception, transportation accidents are considered in Section 5.11 of this document. The transfer of irradiated targets from the reactor to the process facility is evaluated in this section, if the transfer occurs between adjacent facilities and does not require the use of onsite roads.

Table 5-19. Summary of Site Waste Management Cumulative Impacts

Alternatives	Spent Nuclear Fuel	Low-level Waste (liquids)	Low-level Waste (solids)	Incidental Mixed Waste
SNL/NM				
SNF Cumulative Total (Uranium) ^(a)	440 kg	n/a	n/a	n/a
Historical Annual Production ^(b)	n/a	15.74 m ³ /yr	100.7 m ³ /yr	1.80 (l)* m ³ /yr 3.26 (s)* m ³ /yr
Mo-99 Production ^(c,d,e)	57 elements 16 kg/yr	7.3 m ³ /yr	49. m ³ /yr	<.1 m ³ /yr
Interim Storage Capacity for SNF (GIF Pool)	300-1000 elements 84-281 kg	n/a	n/a	n/a
LANL				
SNF Cumulative Total (Uranium) ^(a)	14.0 kg	n/a	n/a	n/a
Historical Annual Production ^(b)	n/a	21,906 m ³ /yr	5765 m ³ /yr	34.1 (l)* m ³ /yr 15.1 (s)* m ³ /yr
Mo-99 Production ^(d,e)	29 elements 32 kg/yr	5.2 m ³ /yr	17.6 m ³ /yr	<.1 m ³ /yr
Interim Storage Capacity for SNF (Omega West & TA-54)	1091 elements 1204 kg	n/a	n/a	n/a
ORNL				
SNF Cumulative Total (Uranium) ^(a)	650 kg	n/a	n/a	n/a
Historical Annual Production ^(b)	n/a	6900 m ³ /yr	2600 m ³ /yr	50,000 m ³ /yr
Mo-99 Production ^(d,e)	22 elements 32 kg/yr	5.2 m ³ /yr	68 m ³ /yr	<0.1 m ³ /yr
Interim Storage Capacity for SNF (ORRR and BSR)	984 elements 1432 kg	n/a	n/a	n/a
INEL				
SNF Cumulative Total (Uranium) ^(a)	261,000 kg	n/a	n/a	n/a
Historical Annual Production ^(b)	n/a	n/a ^(g)	900 m ³ /yr ^(g)	525 m ³ /yr
Mo-99 Production ^(d,e)	17 elements 32 kg/yr	5.2 m ³ /yr	80 m ³ /yr	<0.1 m ³ /yr
Interim Storage Capacity for SNF (IFSF, ICPP-749, ICPP-666)	786 elements 1480 kg	n/a	n/a	n/a
(a) Cumulative totals for spent nuclear fuel based on DOE (1995b). (b) Based upon 1991 annual sitewide rates. (c) These values correspond to 100% replacement of U.S. demand using 15-kW targets; irradiation of targets to 20-kW was assumed for all other alternatives in supplying 100% of the U.S. demand. (d) Mo-99 Production values reflect total generated waste quantities from all three production steps: fabrication, irradiation, and processing. (e) Mass of spent nuclear fuel is based on continuous operation at full power using LEU (20% U-235). (f) Based upon 1995 annual forecasted sitewide rates. (g) Solidified liquid waste volume incorporated in low-level waste total. n/a = Not applicable. SNF = Spent Nuclear Fuel; BSR = Bulk Shielding Reactor. GIF = Gamma Irradiation Facility. IFSF = Irradiated Fuel Storage Facility. ORRR = Oak Ridge Research Reactor. ICPP = Idaho Chemical Processing Plant. * (l) indicates liquid; (s) indicates solid.				

Accident frequencies, as reported in the source documents, safety analysis reports, and related analyses, typically represent the overall probability of the accident, including the probability of the initiating event combined with the frequency of any contributing events required for an environmental release to occur. The contributing events may include equipment or barrier failures, or failures of other mitigating systems designed to prevent accidental releases. In general, the safety documents do not evaluate the consequences of events with expected frequencies of $<10^{-6}$ per year because such accidents are not considered reasonably foreseeable. Thus, all accidents considered here have a 1 in 1,000,000 years, or greater, likelihood of happening.

Accident consequence analyses used release estimates as presented in the source document for a given existing facility or as adapted for this analysis. The downwind concentrations for materials released in accidents were then calculated at a consistent set of receptor locations, as defined for the FEIS. The receptors included a nearby worker who is onsite but outside the facility where the accident takes place, a member of the public who is temporarily at the nearest access location (such as a road that crosses the site, or at the site boundary), and the MEI - offsite resident. Collective dose to the offsite population within 80 km (50 mi) was also calculated for radionuclide releases. Consequences in terms of the involved workers for the representative accident scenarios in each type of facility are discussed as applicable.

The accident evaluation is a conservative scoping analysis intended to identify events that would potentially impact onsite or offsite receptors at levels that could result in health effects, and the exposure pathways that would contribute to those consequences. The scenarios for release of radionuclides or hazardous materials to air or water generally assume some level of mitigation by facility effluent controls; however, no credit is taken for systems designed to prevent or mitigate the emissions from specific types of accidents, such as fire suppression systems.

Individual doses were based on exposure of the receptor during the entire release, except where the release time was sufficiently long that such an assumption is unrealistic. For releases that were expected to last more than a few hours, the exposure duration for onsite workers and members of the public at accessible onsite locations was limited to 2 h, corresponding to the assumed time required to evacuate the candidate site in the event of an accident. Offsite residents were assumed to be exposed during the entire release, regardless of the accident duration. Exposure via inhalation and external pathways (groundshine and submersion in the plume) were considered for workers and the nearest public access receptors; in addition to those pathways, ingestion of contaminated food grown in the downwind sector was evaluated for the offsite population. The ingestion pathway for the population dose was based on where food was grown, and not on the location of the consumers.

Site specific food production data were used for sites when available. Because EPA protective action guidelines specify mitigative actions to prevent consumption of contaminated food, the dose to offsite individuals and populations from inhalation and external pathways is reported separately from the dose including all pathways. If the dose to the maximally exposed individual exceeds specified protective action guidelines, the locally produced food would be kept from the market, and the backyard gardeners would be cautioned not to consume their produce. More realistic potential doses are presented by the

inhalation and external pathways. Ingestion pathways are shown here to represent the maximum potential dose to the local population and to determine the extent to which protective action might be required. Reduced exposure to the plume or to contaminated ground surface as a result of early evacuation of offsite populations was not assumed for the purposes of this analysis, although such actions would also be mandated if the projected dose from an accident exceeded the protective action guidelines.

The expected latent cancer fatalities were calculated by multiplying the potential dose to the population by the latent cancer fatalities risk factor developed in ICRP Publication 60 (ICRP 1991). The latent cancer fatalities for the general population is 0.0005 per person rem, and the latent cancer fatalities for a worker population is 0.0004 per person rem. The total risk to the population of developing any fatal cancers is calculated for each accident scenario. The total risk is the product of the probability the accident happens, the probability of specific wind and stability conditions, and the expected latent cancer fatalities if the accident occurs. Two atmospheric conditions were considered in the accidents, the "median" (expected) conditions that are not exceeded 50% of the time, and the *bounding* conditions that would not be exceeded more than 5% of the time. The bounding conditions have a frequency one-tenth of the median conditions, thus they carry one-tenth the risk of the median conditions. The median (50%) dispersion condition is assumed to have a probability equal to 1.0.

Radiological accidents resulting in the release of radionuclides into the environment were evaluated for the target fabrication, reactor, transport, and hot cell process facilities needed for medical isotope production under each of the alternatives. In general, the accidents evaluated represent the maximum reasonably foreseeable accidents for a given type of facility and are intended to bound the potential risk and consequences of the proposed activities. For each alternative, an analysis was performed for damage to reactor fuel, a target rupture in the reactor pool, a target rupture outside of the reactor pool, and operator error during target processing for both Mo-99 and iodine-125 targets. Except for the fuel damage scenarios, the same estimated release was applied to all the facilities.

The fuel damage scenario differed at SNL/NM because the design of the Annular Core Research Reactor is significantly different from the other reactors. It is physically impossible for the annular core design of the reactor to melt a fuel element because the neutrons are moderated at high temperatures, which in turn will shut down the reactor. Therefore, a physical mechanism (such as, a plane crash or crane drop) would be necessary to rupture a fuel element in the Annular Core Research Reactor. The reactors at the other sites could experience a fuel melt under the conditions described in the analyses. In the accident scenario for SNL/NM, four fuel elements are assumed to be ruptured in a plane crash, whereas in the accident scenarios for the other reactors, one fuel element is assumed to melt. All scenarios represent the bounding design basis accidents for the respective facilities.

The GENII set of computer codes (Napier et al. 1988) was used to perform the downwind 50-yr committed total effective dose equivalent (TEDE) estimates using ICRP 26 (ICRP 1991) and 30 (ICRP 1979-1982) organ-weighted methodology (see Appendix C). Location-specific meteorology and population files were used to model each facility site.

The receptors for each scenario include the nearest uninvolved worker, the nearest point of public access, the nearest resident, and the downwind population in the one sector (out of 16) that has the highest population-weighted concentration in air (that is, the concentration is air times the population for the distance and direction). All sectors and receptor locations are evaluated based on the plume's release height and the local meteorologic data. It should be noted the location of all these receptors are not necessarily in the same direction; thus, in an accident, not all the receptors would receive the reported dose levels simultaneously.

The uninvolved worker is assumed to be working in the onsite location with the highest air concentration. The nearest public access receptor is in the offsite or publicly accessible onsite location with the highest air concentration. Both receptors are assumed to be exposed for 2 h to the plume via external exposure and inhalation. The nearest resident is assumed to be the MEI. The location of the nearest resident is based on actual residences, but the lifestyle of the MEI is hypothetical. The MEI is assumed to grow all his vegetables, meat, and dairy products in his backyard. While at some sites, this clearly is not feasible, it does provide the bounding case beyond which the dose would not be exceeded. The MEI is assumed to be at the house for the entire year, breathing 8766 h/yr, and shielded by the house for an effective exposure to soil contamination of 4383 h/yr. The MEI is assumed to eat 220 kg (485 lb) meat and drink 330 L (87 gal) milk annually. Finally, the sector with the highest population-weighted concentration in air was used to develop the population dose. Sectors with equal population-weighted air concentrations were evaluated using a site-specific food production grid, so the sector with the higher actual food production was chosen for evaluation in this analysis. Where information was available, food production parameters for meat and dairy products were evaluated as a function of distance from the release point, so that all the food produced in that sector was assumed to be consumed. Dose factors per kilogram of meat or liter of milk consumed for each distance were multiplied by the total production at that distance, and the total doses were summed for the sector. The ingestion dose was then added to the external and inhalation doses to obtain the dose for all pathways.

5.15.1 Annular Core Research Reactor: Sandia National Laboratories/New Mexico and the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

5.15.1.1 Target Fabrication at LANL

Radiological Impacts. Target fabrication presents few opportunities for accidents that would cause radioactive material to be released. The only accidents chosen for analysis within LANL's Chemistry and Metallurgy Research facility are an operator dropping a canister of uranium oxide and a solution spill. Solution containing uranium-235 in HNO₃ could be spilled due to earthquake or to operator error (LANL 1993e).

Other accidents were considered, but were not analyzed because no reasonably foreseeable mechanism became apparent by which the accident could occur or produce a radionuclide release to the environment.

Quantities of fissile material handled in a glove box at any given time would not exceed a critical mass; therefore, criticality accidents would be below the threshold of reasonably foreseeable accidents. No flammable materials would be used and welding would be done in an inert atmosphere that would prevent fires. If a worker should drop an open-ended target, no release would be expected because the uranium-235 would be plated onto the tube's inner wall (Massey et al. 1995). The consequences of the canister drop and spill accidents are discussed in the following sections.

Canister Drop. An operator could drop a canister of particulate uranium oxide outside the glove boxes. Administrative controls require that the canister is to be opened only in a glove box. When it is out of the glove box, it is to be kept under double containment. No release would be expected outside the glove box because the uranium oxide is contained in a canister, which is in a sealed plastic bag, which in turn is in an outer canister. The canisters have slip-on tops that are taped in place. If the drop were to occur while the canister is opened in the glove box, the particulate uranium oxide would be contained by the glove box.

Spill. A spill would be unlikely to occur because solutions would be moved using vacuum lines. If a line were to rupture, the solution would tend to stay within the line because of the negative pressure created by the vacuum. However, a major line rupture or an earthquake could cause a solution of uranium-235 in HNO_3 to spill inside a HEPA-filtered glove box. The volume of the spill is assumed to be 5 L based on fabrication processes (Massey et al. 1995).

In the event of a spill, an alarm for evacuation would be sounded by personnel or continuous air monitors. Personnel would be instructed to immediately leave the area. The accident response team, equipped with protective clothing and supplied breathing air, would clean up the spill. Because uranium-235 would be contained within the glove box, no reasonably foreseeable mechanism would exist for a release to occur. No doses to involved personnel, other personnel in the Chemistry and Metallurgy Research Facility, or members of the public would be expected.

Toxicological Impacts. No accidents involving release of toxicological materials were identified. If solution were spilled, any acid fumes in the ventilation system would be neutralized by the NaOH scrubber before leaving the Chemistry and Metallurgy Research Facility stack (Massey et al. 1995).

5.15.1.2 Target Fabrication at SNL/NM

The consequences of accidents during target fabrication at SNL/NM hot cell facilities would be similar to those described in Section 5.15.1.1 for the Chemistry and Metallurgy Research Facility at LANL. As described in that section, no consequences to workers or the public would be expected.

5.15.1.3 Facility Accidents for Target Irradiation at the Annular Core Research Reactor

The analyses for the Annular Core Research Reactor irradiation option assume the reactor is configured in such a manner as to accommodate 80% of the U.S. demand for Mo-99. If the reactor were to be run with 100% of the production, the total number of targets would increase, but the power level and radionuclide inventory per target would decrease. Thus, the resulting risk would be reflected by the analyses presented here.

Analyses in Massey et al. (1995) for the Annular Core Research Reactor included several possible scenarios that could cause four fuel elements to rupture: a plane crash into the facility (but not into the reactor itself) causing the overhead crane to fall into the reactor pool, earthquake also causing the crane to fall, and a transient power pulse that ruptures four fuel elements. The releases for any of the four fuel element ruptures would be the same, but the probability of the plane crashing into the facility was estimated to be the higher than either of the other events, thus it was chosen for evaluation in this FEIS. Other accidents such as fuel handling accidents, reactivity-induced accidents or loss of coolant accidents were evaluated and were not considered to have as great a risk as those chosen for inclusion in this FEIS. In the past, an accident involving the release of radioactive liquids resulted from overfilling the reactor pool. A secondary containment has been added to the facility to prevent release of pool overflow in such an event. With the facility modification, this accident is no longer considered to be reasonably foreseeable.

In addition to potential accidents involving reactor fuel, targets were analyzed for potential releases to the atmosphere (Massey et al. 1995). Two credible bounding accidents were analyzed that might take place during the irradiation of the targets in the Annular Core Research Reactor. The first is a possible rupture of four fuel elements caused by the crash of an airplane into the Annular Core Research Reactor building, resulting in secondary damage to reactor fuel. The second analyzed accident is from a leak in the target, which causes the release of noble gases. The target rupture was assumed to occur with a frequency of 10^{-4} per year. It was further assumed the rupture occurs after a 21-kW, 7-day irradiation, and that all of the noble gases and 1% of the halogens are immediately released from the pool. All of the noble gases and 10% of the remaining halogens were assumed to be released from the stack. These assumptions are conservative; pool releases on the order of 37% of the krypton, 23% of the xenon, and 1.3×10^{-4} % of the iodine are plausible (Massey et al. 1995).

Downwind dose estimates were calculated by conservatively assuming all of the noble gases and halogens for a target or fuel rods were immediately released into the pool. From there, the radionuclides were assumed to be divided into two fractions, one that is released immediately into the atmosphere, and another that is released over time from the evaporation of the pool water. Because the largest fraction of the dose is due to the radionuclides that are immediately released to the atmosphere, only the acute portions were evaluated in these scenarios. The target leak was assumed to occur following a 21-kW, 7-day target irradiation, and the fuel rod ruptures after a 25-kW, 60-day fuel irradiation.

Calculations based on the frequency of airplane traffic, the area of the facility, and industry probabilities of crashes indicate the estimated probability of an aircraft crash into the Annular Core Research Reactor facility is about 5×10^{-5} per year, or one crash expected in 20,000 years. If an airplane were to crash into the Annular Core Research Reactor building, no release of materials would occur, unless targets or fuel elements were ruptured. In the interest of bounding the risks of an airplane crash, it is assumed the crash results in the bridge crane falling into the reactor pool and rupturing four fuel elements. The radionuclides expected to be released are shown in Table 5-20, and the consequences of such an accident are shown in Table 5-21. The maximum public individual dose from an airplane crash would be 200 mrem for a resident located 5400 m (3.4 mi) from Technical Area V. The limiting MEI organ dose would be 4.2 rem to the thyroid with ingestion and 53 mrem without ingestion. If the accident occurs, the airplane crash would result in at most one latent cancer fatality. This translates into an average annual accident risk of 6×10^{-6} or the chance of any individual in the affected population dying of a cancer from a plane crash rupturing four fuel elements is about 1 in 200,000 per year of operation. For facility workers, it is assumed that anyone in the facility during an airplane crash would be killed by the impact, building collapse, or subsequent fires; therefore, worker doses were calculated only for onsite non-involved workers.

The previous plane crash scenario analysis evaluates the secondary effects from a plane crashing into the reactor building, but not into the reactor core itself. The probability of an airplane crash resulting in a

Table 5-20. Radionuclides Released from Annular Core Research Reactor During a Postulated Four Fuel Element Rupture Scenario (Massey et al. 1995)

Isotope	Release (Ci)	
	Immediate	Delayed
Bromine-83	0.44	--
Krypton-83m	444.0	610.0
Krypton-85 m	1056.0	11.2
Krypton-85	2.39	--
Krypton-87	2140.0	22.0
Krypton-88	3020.0	--
Iodine-130	0.00148	--
Iodine-131	2.35	--
Xenon-131m	24.2	1610.0
Iodine-132	35.5	3.55
Iodine-133	5.6	--
Xenon-133m	163.0	63.2
Xenon-133	5600.0	916.0
Iodine-134	7.4	6.4
Iodine-135	5.2	--
Xenon-135	2020.0	3780.0

Table 5-21. Dose and Consequences for the Four Fuel Element Rupture Accident at the Annular Core Research Reactor (Massey et al. 1995)

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (300 m N)	Public Access Location (5400 m N)	Individual Resident (5400 m N)	
			All Pathways	External and Inhalation
TEDE (rem)	0.38	0.075	0.20	0.076
Collective Impacts to Population within 80 km to the North (n = 133,266)				
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	151	150	2350	2300
Fatal Cancers	0.075	0.075	1	1
Cancer Risk	4×10^{-6}	4×10^{-6}	6×10^{-6}	6×10^{-6}

large portion of the aircraft crashing directly into the 3.6-m (12-ft) diameter Annular Core Research Reactor pool and then impacting the core 9.1 m (30 ft) below water was evaluated but the probability was determined to be so low (about 1 in a billion per year), this crash was not analyzed (Massey et al. 1995).

It should also be noted that it would be possible for a single fuel element to rupture as a result of mechanical failure. The probability of this occurring is 0.001 per year of operation. The potential dose resulting from this type of accident would be one-fourth that shown in Table 5-21. The maximum public individual dose from a single fuel rupture would be 50 mrem for a resident located 5400 m (3.4 mi) from Technical Area V. The limiting MEI organ dose would be 1.0 rem to the thyroid with ingestion, or 13 mrem without ingestion. The fuel element rupture would result in less than 1 (0.30) latent cancer fatality if the accident occurs. This translates into an average annual accident risk of 3×10^{-5} or the chance of any individual in the affected population dying of cancer from a fuel element rupture would be about 1 in 30,000 per year of operation.

If a worker were in the Annular Core Research Reactor high bay when a single fuel element ruptured, the worker would be immediately notified of the rupture by various alarms and detectors in the reactor and reactor area. The worker would then immediately evacuate the area and not return until safe conditions were established or would use protective equipment. If the worker did remain in the high-bay for 5 min to perform a safety task, and the worker was assumed to be exposed to 10% of the total nobles and halogens immediately released into the high-bay atmosphere (1% of the total halogens and fission products being respirable), the worker would receive an estimated 80 rem (Massey et al. 1995).

The estimated radionuclide release from the 16.5 m Annular Core Research Reactor stack following a target rupture is shown in Table 5-22 and consequences for the accident are shown in Table 5-23. The maximum public individual dose from a target rupture accident would be 27 mrem for a resident located 5400 m (3.4 mi) from Technical Area V. The limiting MEI organ dose would be 0.38 rem to the thyroid with ingestion, 6.8 mrem without ingestion. This accident would result in less than 1 (0.24) latent cancer fatality if the accident occurs. This translates into an average annual accident risk of 2×10^{-5} or the chance of latent cancer fatalities in the population from a target rupture accident would be about 1 in 50,000 per year of operation.

5.15.1.4 Transfer of Irradiated Target from the Annular Core Research Reactor to the Hot Cell Facility

Two bounding accidents were considered during the transfer of the target from the reactor to the Hot Cell Facility/Chemistry and Metallurgy Research Facility/hot cells. An accident causing an uncontained target to rupture bounds the risk for offsite residents and population, and direct exposure of a worker to an unshielded target bounds the radiological risk to a worker. Other accidents were considered, but these two accidents bounded the risks.

Table 5-22. Radionuclides Released from the Annular Core Research Reactor During a Postulated Target Rupture Scenario (Massey et al. 1995)

Isotope	Stack Release (Ci)	
	Immediate	Delayed
Bromine-83	0.094	--
Krypton-83m	94.0	128.0
Krypton-85 m	223.0	2.0
Krypton-85	0.057	--
Krypton-87	450.0	4.0
Krypton-88	640.0	--
Iodine-130	0.00019	--
Iodine-131	0.022	--
Xenon-131m	0.468	155.0
Iodine-132	0.58	--
Iodine-133	1.2	--
Xenon-133m	28.3	13.2
Xenon-133	613.0	191.0
Iodine-134	1.3	--
Iodine-135	1.1	--
Xenon-135	113.0	798.0

Table 5-23. Dose and Consequences for the Target Rupture Accident at the Annular Core Research Reactor

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (300 m N)	Public Access Location (5400 m N)	Individual Resident (5400 m N)	
			All Pathways	External and Inhalation
TEDE (rem)	0.089	0.016	0.027	0.016
	Collective Impacts to Population within 80 km to the North (n = 133,266)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	33.0	33.0	485.0	480.0
Fatal Cancers	0.017	0.017	0.24	0.24
Cancer Risk	2×10^{-6}	2×10^{-6}	2×10^{-6}	2×10^{-6}

The bounding impact for all target transfer operations would be represented by the rupture of a single target as the result of a manned transport accident while in transit between the Annular Core Research Reactor and the Hot Cell Facility. Although highly improbable (estimated probability is less than 1×10^{-6} per year), this accident scenario assumes the loss of all noble gas radionuclides and 1% of halogen radionuclides directly to the atmosphere (Table 5-24). Downwind dose estimates for a cask transport accident between the Annular Core Research Reactor and the Hot Cell Facility are presented in Table 5-25. It was assumed that a rupture occurs after a 21-kW, 7-day irradiation, and that all of the noble gases and 1% of the halogens were immediately released from one target into the atmosphere. The maximum public individual dose from a Mo-99 target transfer accident would be 130 mrem for a resident located 5400 m (3.4 mi) from Technical Area V. The limiting MEI organ dose would be 3.8 rem to the thyroid with ingestion, and 0.068 mrem without ingestion. This accident would result in less than 1 (0.32) latent cancer fatalities if the accident occurs. This number translates into an average annual accident risk.

The postulated accident scenario for direct exposure to an involved worker assumed that all safety features fail and that a worker is inadvertently exposed to an irradiated target. No shielding, other than the target cladding and air is present. The worker retreats to a safe distance. In the bounding scenario, the target is allowed to cool 2 hours. The worker is standing 1 m from the target for 10 s before the worker becomes aware of the danger, either visually or from audio/visual radiation alarms. The worker retreats at a walking speed of 2 m/s. The total dose to the worker was estimated to be about 30 rem (Massey et al. 1995).

Table 5-24. Radionuclides Released to the Atmosphere During a Postulated Target Rupture Scenario During Transfer (Massey et al. 1995)

Isotope	Transfer Release (Ci)
Bromine-83	0.94
Krypton-83m	94.0
Krypton-85m	220.0
Krypton-85	0.057
Krypton-87	450.0
Krypton-88	640.0
Iodine-130	0.0019
Iodine-131	2.2
Xenon-131m	0.47
Iodine-132	5.8
Iodine-133	12.0
Xenon-133m	28.0
Xenon-133	610.0
Iodine-134	13.0
Iodine-135	11.0
Xenon-135	110.0

Table 5-25. Dose and Consequences for Release from a Single Target Rupture at SNL/NM During Target Transfer Following Target Irradiation

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (300 m N)	Public Access Location (5400 m N)	Individual Resident (5400 m N)	
			All Pathways	External and Inhalation
TEDE (rem)	0.1	0.018	0.13	0.018
	Collective Impacts to Population within 80 km to the North (n = 133,266)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	40.0	38.0	640.0	590.0
Fatal Cancers	0.02	0.019	0.32	0.3
Cancer Risk	2×10^{-8}	2×10^{-8}	3×10^{-8}	3×10^{-8}

5.15.1.5 Target Processing at SNL/NM Hot Cell Facilities

Accidents evaluated for analysis during target processing included an airplane crash, a fire, target process spill, and release of process gases. The probability of an airplane crash into the Hot Cell Facility, a fire, and a process spill, as well as the respective potential doses from these accidents were much smaller than the probability and consequences from an operator inadvertently opening process valves, sending noble gases up the Hot Cell Facility stack. Thus, the operator error scenario was chosen to bound the risks from other accidents.

The bounding accident for target processing is based on an analysis developed for the LANL hot cells at the Chemistry and Metallurgy Research Facility (LANL 1993e). An operator could inadvertently open the wrong valves at the wrong temperature, or mechanical failures of valves or transfer lines could occur. The loss of fission products would be inside the hot cells and most of the fission products would be contained on the charcoal or HEPA filters. Noble gases, however, would be vented to the SNL/NM Hot Cell Facility stack. The release consists of noble gases that are released through the 38-m (124.6-ft) Hot Cell Facility stack at SNL/NM. It was assumed the targets were irradiated for 7 days at 20 kW power, and they had cooled for 16 h before the release. A total of 1550 Ci of noble gases would be released; their proportions were assigned based on the above power rating of the targets. The frequency for this event would be once per year ($p = 1.0$) based on the number of targets being processed yearly and the estimated frequency of human error that would cause the release. The estimated release is shown in Table 5-26, and the doses are shown in Table 5-27. The maximum public individual dose from a Mo-99 target processing accident would be 0.74 mrem for a resident located 5400 m (3.4 mi) from Technical Area V. The limiting MEI organ dose would be 0.035 mrem to the lung. This accident would result in less than 1 (0.016) latent cancer fatality if the accident occurs. This figure translates into an annual accident risk of 2×10^{-3} , or the chance of any individual dying of cancer from a Mo-99 target rupture accident is about 1 in 500 per year of operation.

Table 5-26. Estimated Releases from the Hot Cell Facility Accident During Mo-99 Target Processing

Radionuclide	Release (Ci)
Krypton-83m	3.5
Krypton-85m	0.26
Krypton-87	0.074
Krypton-88	13.0
Xenon-133	600.0
Xenon-133m	95.0
Xenon-135	610.0
Xenon-135m	230.0

Table 5-27. Dose and Consequences for an Accidental Release from the Hot Cell Facility at SNL/NM During Mo-99 Target Processing

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (300 m N)	Public Access Location (5400 m N)	Individual Resident (5400 m N)	
			All Pathways	External and Inhalation
TEDE (rem)	0.0038	0.00074	0.00074	0.00074
	Collective Impacts to Population within 80 km to the North (n = 133,266)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	2.6	2.6	32.0	32.0
Fatal Cancers	0.0013	0.0013	0.016	0.016
Cancer Risk	1×10^{-3}	1×10^{-3}	2×10^{-3}	2×10^{-3}

An analysis was also performed for the processing of targets to extract iodine-125. If valves were opened in the wrong sequence, fission product gases could be released from the Hot Cell Facility stack. A probability of 0.1 was assumed for the frequency of occurrence because it would be caused by operator error (LANL 1993e). The number of iodine-125 targets being irradiated each year would be significantly lower than for Mo-99 processing; therefore, the accident frequency is lower for iodine-125 target processing.

In this scenario, 72 h after irradiation, cold trap valves would be left open when the gas is being transferred between decay storage vessels. The estimated release consists of 31 Ci of xenon-125. Iodine-125 and other radionuclides would be present, but filters at the stack would capture all the iodine-125, and the dose is dominated by xenon-125. Results of the dose calculations are shown in Table 5-28. The maximum public individual dose from a iodine-125 target processing accident would be 1.9 mrem for a resident located 5400 m (3.4 mi) from Technical Area V. The limiting MEI organ dose would be 63 mrem to the thyroid with ingestion and 0.12 mrem without ingestion. This accident would result in less than 1 (0.00075) latent cancer fatality, if the accident occurs, because the population would not be allowed to

Table 5-28. Dose and Consequences for an Accidental Release from the SNL/NM Hot Cell Facility During Iodine-125 Target Processing

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (100 m N)	Public Access Location (5400 m N)	Individual Resident (5400 m N)	
			All Pathways	External and Inhalation
TEDE (rem)	0.000089	0.000026	0.0019	0.000027
Collective Impacts to Population within 80 km to the North (n = 133,266)				
		Median Atmospheric Dispersion		Bounding Atmospheric Dispersion
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	0.084	0.084	1.5	1.5
Fatal Cancers	0.000042	0.000042	0.00075	0.00075
Cancer Risk	4×10^{-6}	4×10^{-6}	3×10^{-5}	3×10^{-5}

consume the dairy and beef products grown in the region until the risk had been appreciably reduced. This translates into an average annual accident risk of less than 3×10^{-5} or the chance of any individual dying of cancer from an iodine-125 target processing accident is about 1 in 10,000 per year of operation.

5.15.2 Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

5.15.2.1 Target Fabrication at the Chemistry and Metallurgy Research Facility

No effects are expected from the fabrication of targets at the Chemistry and Metallurgy Research Facility for the reasons explained in Section 5.15.1.1.

5.15.2.2 Target Irradiation at the Omega West Reactor - Air Release Scenarios

The Omega West Reactor Safety Evaluation Report (Smith and Bunker 1989) evaluated reactivity accidents, equipment failures, earthquakes, floods and tornadoes, and loss-of-coolant accidents, as well as the maximum credible accident. The maximum credible accident bounds the consequences from the other accident types and was chosen for inclusion in this FEIS. The maximum credible accident for the Omega West Reactor is assumed to be the blockage of coolant flow through a single fuel element by a single piece of material, resulting in melting of fuel (Smith and Bunker 1989). This scenario assumes that one element is completely blocked at the upper end boxes. First boiling and then steam voiding of the water remaining in the element would occur. It is assumed that 50% of the fuel would melt within seconds. This scenario could release 100% of the xenon and krypton gases, as well as iodine dissolved in the reactor water. The

estimated frequency of the accident was 10^{-6} to 10^{-4} per year. The releases from the 45-m stack are shown in Table 5-29, and the dose consequences are shown in Table 5-30. The maximum public individual dose from a fuel element melt would be 5.5 rem for a resident located 1300 m (0.9 mi) from the Omega West Reactor.

Table 5-29. Radionuclides Released from the Omega West Reactor During a Postulated Fuel Melt Scenario (Smith and Bunker 1989)

Isotope	Release (Ci)
Iodine-131	120
Xenon-131m	24
Other iodines modeled as Iodine-134	1,600
Other noble gases modeled as Krypton-88	21,000

Table 5-30. Dose and Consequences for an Accidental Fuel Melt Release from the Omega West Reactor

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (200 m NNW)	Public Access Location (300 m N)	Individual Resident (1300 m N)	
			All Pathways	External and Inhalation
TEDE (rem)	0.82	0.67	5.7 ^(a)	0.48
	Collective Impacts to Population within 80 km to the Northwest (Affected Population = 4743)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	91.0	91.0	940	930
Fatal Cancers	0.046	0.046	0.47	0.47
Cancer Risk	5×10^{-6}	5×10^{-6}	5×10^{-6}	5×10^{-6}
(a) Protective Action Guidelines would require intervention of locally grown food products.				

The limiting MEI organ dose would be 170 rem to the thyroid with ingestion and 1.5 rem without ingestion. This accident would result in less than 1 (0.47) latent cancer fatality because the population would not be allowed to consume the dairy and beef products grown in the region until the risk had been appreciably reduced. This translates into an average annual accident risk of 5×10^{-6} or the chance of any individual dying of cancer from a fuel element melt accident is about 1 in 200,000 per year of operation.

Rupture of a target following irradiation would release radionuclides in the amounts shown in Table 5-22. The estimated dose and consequences are shown in Table 5-31. The maximum public individual dose from a Mo-99 target rupture accident would be 27 mrem for a resident located 1300 m (0.9 mi) from the Omega West Reactor. The limiting MEI organ dose would be 330 mrem to the thyroid with ingestion and 5.8 mrem without ingestion. This accident would result in less than 1 (0.02) latent cancer fatality if the accident occurs. This translates into an average annual accident risk of 2×10^{-7} or the chance of any individual dying of cancer from a Mo-99 target rupture accident is about 1 in 5 million per year of operation.

Table 5-31. Dose and Consequences for an Accidental Target Rupture from the Omega West Reactor

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (200 m NNW)	Public Access Location (300 m N)	Individual Resident (1300 m N)	
			All Pathways	External and Inhalation
TEDE (rem)	0.033	0.028	0.027	0.017
	Collective Impacts to Population within 80 km to the Northwest (Affected Population = 4743)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	3.5	3.5	33.0	33.0
Fatal Cancers	0.0018	0.0018	0.017	0.017
Cancer Risk	2×10^{-7}	2×10^{-7}	2×10^{-7}	2×10^{-7}

5.15.2.3 Target Irradiation at the Omega West Reactor - Liquid Release Scenario

A liquid release scenario was evaluated in conjunction with the target rupture scenario at the Omega West Reactor described previously (LANL 1993e). In this case, it was assumed that a leak in the reactor coolant circulation system occurred simultaneously with the target rupture, releasing radioactive materials to the ground and ultimately to an onsite stream. Release of fission gases to the 62,000 L (16,500 gal) tank was as described for the target rupture scenario, and the coolant leak was assumed to be diluted 2:1 by water in the stream. The TEDE was calculated for a hypothetical hiker who might drink 2 L of water from the stream after a delay of 24 h following release from the reactor. No adsorption or delay of radionuclides in the soil was assumed; only radioactive decay and dilution in the stream were accounted for in estimating the radionuclide intake by the hiker.

The TEDE to the hiker was estimated, using radionuclide intake-to-dose conversion factors as published by EPA (1988), to be 0.24 rem (see Table 5-32). The frequency of the accident is estimated as the product of the frequency of the target failure (about 0.1/yr) and the frequency of the leak (conservatively estimated as 0.05), or about 5×10^{-3} .

Table 5-32. Estimated Dose to an Individual Hiker from a Coolant Leak at the LANL Omega West Reactor

Radio-nuclides	Concentrations in Reactor Pool, Ci/L	Concentrations in Stream, Ci/L	Radionuclide Intake by Hiker, Ci	Effective Dose Equivalent, rem
Iodine-131	7.0×10^{-6}	2.1×10^{-6}	4.3×10^{-6}	0.23
Iodine-132	3.2×10^{-7}	8.9×10^{-11}	1.8×10^{-10}	1.2×10^{-7}
Iodine-133	4.6×10^{-6}	6.8×10^{-7}	1.4×10^{-6}	0.014
Iodine-134	3.8×10^{-7}	5.4×10^{-16}	1.1×10^{-15}	2.7×10^{-13}
Iodine-135	3.5×10^{-6}	1.0×10^{-7}	2.0×10^{-7}	4.5×10^{-4}
Total				0.24

5.15.2.4 Target Irradiation at the Omega West Reactor - Flooding Potential

A recent safety evaluation described potential flooding from a 100-year rainfall event in addition to water from failure of the Los Alamos Dam and water-storage tanks. The peak discharge from this analysis was estimated at 63 m^3 (2260 ft^3) per second, which was approximately 30 m^3 (1060 ft^3) per second greater than the peak discharge at TA-2 from a 100-year rainfall event estimated without dam and storage tanks failure. Even with the excess flood waters, the estimate for overflow would not reach the finished floor elevation.

Becker (1991) performed an analysis in nearby Potrillo Canyon, 3 mi south of TA-2. The analysis indicates that over the last 80 years, only some runoff events were large enough to travel through the bottom half of the Potrillo Canyon watershed. These runoffs occurred in 1911, 1913, 1916, 1952, 1957, and 1968. The last breakthrough occurred in 1968 in Potrillo Canyon. The report also stated that individual rain events by themselves may not be related to runoff occurrence, but sequences of rainfall over time appear to be related to runoff events. This report also concluded that significant runoff events are not necessarily related to the results of catastrophic weather events. Although Potrillo Canyon is smaller than Los Alamos Canyon, Becker (1991) implies that a large runoff event to produce significant flow through the canyons is a relatively rare occurrence (for instance, 6 events in 80 years).

5.15.2.5 Target Irradiation at the Omega West Reactor - Falling Boulders

The Omega West Reactor sits in a canyon with a cliff face immediately above it. A retaining wall would be constructed sufficiently strong to stop a falling boulder, thus mitigating any potential impact on the building, if the reactor is restarted for production of medical isotopes.

Table 5-33. Dose and Consequences for an Accidental Release During Mo-99 Target Transfer at the Omega West Reactor

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (200 m W)	Public Access Location (100 m W)	Individual Resident (1300 m N)	
			All Pathways	External and Inhalation
TEDE (rem)	0.037	0.003	0.12	0.019
Collective Impacts to Population within 80 km to the Northwest Affected Population = 4743)				
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	10.0	10.0	38.0	38.0
Fatal Cancers	0.05	0.05	0.019	0.019
Cancer Risk	5×10^{-8}	5×10^{-8}	2×10^{-7}	2×10^{-8}

The bounding target processing accident described in Section 5.15.1.5 was developed for the Chemistry and Metallurgy Research Facility. The release is the same as is shown in Table 5-26, but would be released from the 17-m Chemistry and Metallurgy Research Facility stack. The estimated dose and consequences are shown in Table 5-34. The maximum public individual dose from a Mo-99 target processing accident would be 9 mrem for a resident located 1010 m (0.6 mi) from the Chemistry and Metallurgy Research Facility. The limiting MEI organ dose would be 0.2 mrem to the lung. This accident would result in less than 1 (0.005) latent cancer fatality if the accident occurs. This number translates into an average annual accident risk of 5×10^{-4} or the chance of any individual dying of cancer from a Mo-99 target processing accident is about 1 in 2000 per year of operation.

The iodine-125 accident described in Section 5.15.1.5 was applied to the Chemistry and Metallurgy Research Facility. The dose and consequences are shown in Table 5-35. The maximum public individual dose from an iodine-125 target processing accident would be 5.7 mrem for a resident located 1010 m (0.6 mi) from the Chemistry and Metallurgy Research Facility. The limiting MEI organ dose would be 180 mrem to the thyroid with ingestion and 0.33 mrem without ingestion. This accident would result in less than 1 (0.00065) latent cancer fatality if the accident occurs. This number translates into an average annual accident risk of 7×10^{-6} or the chance of any individual dying of cancer from an iodine-125 target processing accident is about 1 in 100,000 per year of operation.

Table 5-34. Dose and Consequences for an Accidental Release from the Chemistry and Metallurgy Research Facility Hot Cells from Processing Mo-99 Targets

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (100 m NNW)	Public Access Location (200 m E)	Individual Resident (1010 m N)	
			All Pathways	External and Inhalation
TEDE (rem)	0.030	0.030	0.0089	0.0089
Collective Impacts to Population within 80 km to the East by Northeast (Affected Population = 26,760)				
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	1.8	1.8	10.0	10.0
Fatal Cancers	0.0009	0.0009	0.005	0.005
Cancer Risk	9×10^{-4}	9×10^{-4}	5×10^{-4}	5×10^{-4}

Table 5-35. Dose and Consequences for an Accidental Release from the Chemistry and Metallurgy Research Facility Hot Cells from Processing of Iodine-125 Targets

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (100 m W)	Public Access Location (100 m W)	Individual Resident (1010 m N)	
			All Pathways	External and Inhalation
TEDE (rem)	0.00069	0.00069	0.0057	0.00025
Collective Impacts to Population within 80 km to the East-by-Northeast (Affected Population = 26,760)				
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	0.14	0.048	1.3	0.53
Fatal Cancers	0.00007	0.0000028	0.00065	0.00027
Cancer Risk	7×10^{-6}	3×10^{-7}	7×10^{-6}	3×10^{-6}

5.15.3 Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory Alternative

5.15.3.1 Target Fabrication at Oak Ridge National Laboratory Hot Cells

No effects from the fabrication of Mo-99 targets are expected due to the reasons discussed in Section 5.15.1.1

5.15.3.2 Target Irradiation at Oak Ridge Research Reactor

The design of the Oak Ridge Research Reactor is similar to that of the Omega West Reactor. Both reactors use the same fuel configuration and would be run at the same power level for target irradiation. Therefore, the same release estimate (Table 5-29) was used for the potential release during a fuel melt accident but would be released from the 76-m (249.3-ft) Oak Ridge Research Reactor stack. Other accidents evaluated in the Oak Ridge Research Reactor SAR were found to be either incredible (100% fuel melt accident) or credible with significantly lower doses (reactivity or loss of coolant accidents) than postulated for the Omega West Reactor design basis accident (Binford et al. 1968). Thus, quantitative descriptions from the Omega West Reactor SAR were used in developing the maximum credible accident at the Oak Ridge Research Reactor. The consequences of the fuel melt accident are shown in Table 5-36.

Table 5-36. Dose and Consequences for an Accidental Fuel Melt Release from the Oak Ridge Research Reactor

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (300 m W)	Public Access Location (400 m NE)	Individual Resident (5450 m E)	
			All Pathways	External and Inhalation
TEDE (rem)	0.17	0.14	0.42	0.037
	Collective Impacts to Population within 80 km to the East (Affected Population = 241,081)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	5400.0	750.0	11000.0	1400.0
Fatal Cancers	3	0.38	6	0.70
Cancer Risk	3×10^{-4}	4×10^{-5}	6×10^{-5}	7×10^{-6}

The maximum public individual dose from a fuel element melt would be 420 mrem for a resident located 5450 m (3.4 mi) from Oak Ridge Reservation. The limiting MEI organ dose would be 13 rem to the thyroid with ingestion and 110 mrem without ingestion. This accident would result in 6 latent cancer fatalities if the accident occurs. This figure translates into an average annual accident risk of 6×10^{-5} or the chance of any individual dying of cancer from a fuel element melt accident is about 1 in 20,000 per year of operation.

The target rupture following irradiation at Oak Ridge Research Reactor uses the same estimated release as shown in Table 5-22. Consequences from the release are shown in Table 5-37. The maximum public individual dose from a Mo-99 target rupture accident would be 2 mrem for a resident located 5450 m (3.4 mi) from Oak Ridge Reservation. The limiting MEI organ dose would be 26 mrem to the thyroid with ingestion and 0.44 mrem without ingestion. This accident would result in less than 1 (0.031) latent cancer fatality if the accident occurs. This number translates into an average annual accident risk of 3×10^{-7} or the chance of any individual dying of cancer from a Mo-99 target rupture accident is about 1 in 3 million per year of operation

5.15.3.3 Target Transfer from the Oak Ridge Research Reactor to the Hot Cells

Two bounding accidents were considered during the transfer of the target from the reactor to the ORNL Hot Cell Facility. An accident causing an uncontained target to rupture bounds the risk for offsite residents and population, and direct exposure of a worker to an unshielded target bounds the radiological risk to a worker. Other accidents were considered, but the resulting consequences and risks were lower.

Table 5-37. Dose and Consequences for the Target Rupture Accident at Oak Ridge Research Reactor

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (300 m W)	Public Access Location (400 m NE)	Individual Resident (5450 m E)	
			All Pathways	External and Inhalation
TEDE (rem)	0.099	0.091	0.002	0.0012
	Collective Impacts to Population within 80 km to the East (Affected Population = 241,081)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	33.0	24.0	61.0	43.0
Fatal Cancers	0.017	0.012	0.031	0.022
Cancer Risk	2×10^{-6}	1×10^{-6}	3×10^{-7}	2×10^{-7}

The bounding impact for all target transfer operations would be represented by the rupture of a single target as the result of a manned transport accident while in transit between the Oak Ridge Research Reactor and the ORNL Hot Cell Facility. Although highly improbable (estimated probability is less than 1×10^{-6} per year), this accident scenario assumes the loss of all noble gas radionuclides and 1% of halogen radionuclides directly to the atmosphere (Table 5-24). Downwind dose estimates for a cask transport accident between the Oak Ridge Research Reactor and the ORNL Hot Cell Facility are presented in Table 5-38. It was assumed that rupture occurs after a 21-kW, 7-d irradiation, and that all of the noble gases and 1% of the halogens were immediately released from one target into the atmosphere at ground level. The maximum public individual dose from a Mo-99 target transfer accident would be 81 mrem for a resident located 5450 m (3.4 mi) from Oak Ridge Reservation. The limiting MEI organ dose would be 2.3 rem to the thyroid with ingestion and 40 mrem without ingestion. This accident would result in less than 1 (0.5) latent cancer fatality if the accident occurs. This number translates into an average annual accident risk of 5×10^{-7} or the chance of any individual dying of cancer from a target transfer accident is about 1 in 2 million per year of operation.

Due to the extremely high speeds and the impact severity necessary to breach the transportation cask, it is assumed that the worker who would be driving the transport vehicle would likely be killed by the impact of the mobile transport accident. The immediate fatality of the worker(s) involved in the transportation accident would bound the risk of the worker dying from a fatal cancer due to any dose received from the accident. Therefore, the dose to the worker was not estimated.

Table 5-38. Dose and Consequences for an Accidental Release from Target Rupture at Oak Ridge National Laboratory During Mo-99 Target Transfer

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (300 m W)	Public Access Location (400 m NE)	Individual Resident (5450 m E)	
			All Pathways	External and Inhalation
TEDE (rem)	0.79	0.48	0.081	0.013
	Collective Impacts to Population within 80 km to the East (Affected Population =241,100)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	150.0	25.0	1000.0	180
Fatal Cancers	0.075	0.0013	0.5	0.09
Cancer Risk	8 x 10 ⁻⁸	1 x 10 ⁻⁹	5 x 10 ⁻⁷	9 x 10 ⁻⁹

The risk to an involved worker would be identical to that discussed in Section 5.15.1.4 for the worker's direct exposure to the target. The total dose received by a worker so exposed would be about 30 rem.

5.15.3.4 Target Processing at Oak Ridge National Laboratory Hot Cells

Accidents evaluated for analysis during target processing included a fire, target process spill, and release of process gases. The probability of a fire and a process spill, as well as the respective potential doses from these accidents, was much smaller than the probability and consequences from an operator inadvertently opening process valves, sending noble gases up the hot cell facility stack. Thus the operator error scenario was chosen to bound the risks from other accidents.

The target processing accidents described in Section 5.15.1 were developed for the Chemistry and Metallurgy Research Facility, and were applied to the ORNL hot cells as a bounding case for Mo-99 and iodine-125 production. The release for the Mo-99 production accident is the same as is shown in Table 5-26, and the release for iodine-125 target processing is as described in Section 5.15.1.5. The dose and consequences are shown in Tables 5-39 and 5-40. The maximum public individual dose from a Mo-99 target processing accident would be 0.13 mrem for a resident located 5450 m (3.4 mi) from the ORNL Hot Cell Facility. The limiting MEI organ dose would be 0.005 mrem to the lung. This accident would result in less than 1 (0.0024) latent cancer fatality if the accident occurs. This figure translates into an average annual accident risk of 2×10^{-4} or the chance of latent cancer fatalities in the population from a Mo-99 target processing accident at Oak Ridge is about 1 in 4000 per year of operation.

Table 5-39. Dose and Consequences for the Accidental Release of Noble Gases from Mo-99 Target Processing at the ORNL Hot Cell Facility

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (300 m W)	Public Access Location (400 m NE)	Individual Resident (5450 m E)	
			All Pathways	External and Inhalation
TEDE (rem)	0.00086	0.00071	0.00013	0.00013
	Collective Impacts to Population within 80 km to the East (Affected Population = 241,081)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	Without Ingestion	All Pathways	Without Ingestion
	2.5	2.5	4.8	4.8
Collective TEDE (person-rem)	0.0013	0.0013	0.0024	0.0024
Fatal Cancers	1×10^{-3}	1×10^{-3}	2×10^{-4}	2×10^{-4}
Cancer Risk				

Table 5-40. Dose and Consequences for the Accidental Release of Noble Gases from Iodine-125 Target Processing at the ORNL Hot Cell Facility

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (300 m W)	Public Access Location (400 m NE)	Individual Resident (5450 m E)	
			All Pathways	External and Inhalation
TEDE (rem)	0.00002	0.000016	0.00019	0.0000043
	Collective Impacts to Population within 80 km to the East (n= 241,081)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	5.5	0.093	2.2	0.22
Fatal Cancers	0.0028	0.000047	0.011	0.00008
Cancer Risk	3×10^{-4}	5×10^{-6}	1×10^{-4}	8×10^{-7}

The maximum public individual dose from an iodine-125 target processing accident would be 0.19 mrem for a resident located 5450 m (3.4 mi) from ORNL Hot Cell Facility. This accident would result in less than 1 (0.01) latent cancer fatality if the accident occurs. The limiting MEI organ dose would be 6.3 mrem to the thyroid with ingestion and 0.012 mrem without ingestion. This number translates into an average annual accident risk of 1×10^{-4} or the chance of latent cancer fatalities in the population from an iodine-125 target processing accident is about 1 in 10,000/yr of operation.

5.15.4 Power Burst Facility/Test Area North: Idaho National Engineering Laboratory Alternative

5.15.4.1 Target Fabrication at Test Area North Hot Cells

No effects from target fabrication would be expected due to the reasons discussed in Section 5.15.1.1.

5.15.4.2 Target Irradiation at the Power Burst Facility

The design of the Power Burst Facility is similar to that of the Omega West Reactor. Therefore, the same estimated release (Table 5-29) was used for the potential fuel melt accident. The Power Burst Facility SAR evaluated the potential doses from a variety of design basis accidents, (for example, flow blockage accident, loss-of-coolant accident, loop coolant system blowdown, and fuel handling accident) (ANC 1971). In all cases, the design basis accident described in the Omega West Reactor SAR bounded

the consequences, and, thus, quantitative descriptions from the Omega West Reactor SAR were used in developing the maximum credible accident at the Power Burst Facility.

The consequences of the fuel melt accident are shown in Table 5-41. The maximum public individual dose from a fuel element melt would be less than 1.6 rem for a resident located 12,400 m (7.7 mi) from the Power Burst Facility. The limiting MEI organ dose would be 50 rem to the thyroid with ingestion and 440 mrem without ingestion. This accident would result in 4 latent cancer fatalities if the accident occurs. This translates to an average annual accident risk of 4×10^{-5} or the chance of latent cancer fatalities in the population from a fuel element melt accident is about 1 in 30,000 per year of operation.

The target rupture following irradiation at the Power Burst Facility uses the same estimated release as in Table 5-22. Consequences from the release are shown in Table 5-42. The maximum public individual dose from a Mo-99 target rupture accident would be 5.9 mrem for a resident located 12,400 m (7.7 mi) from the Power Burst Facility. The limiting MEI organ dose would be 96 mrem to the thyroid with ingestion and 1.6 mrem without ingestion. This accident would result in less than 1 (0.008) latent cancer fatality if the accident occurs. This translates to an average annual accident risk of 8×10^{-8} or the chance of latent cancer fatalities in the population from a Mo-99 target rupture accident is about 1 in 10 million per year of operation.

Table 5-41. Dose and Consequences for the Fuel Melt Accident at Power Burst Facility

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (300 m ESE)	Public Access Location (1000 m S)	Individual Resident (12,400 m SE)	
			All Pathways	External and Inhalation
TEDE (rem)	1.2	1.3	1.6 ^(a)	0.099
	Collective Impacts to Population within 80 km to the East (n= 70, 150)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	900.0	20.0	7300.0	170.0
Fatal Cancers	0.12	0.010	4.0	0.085
Cancer Risk	1×10^{-5}	1×10^{-6}	4×10^{-5}	9×10^{-7}
(a) Protective Action Guides would require intervention of locally grown food products.				

Table 5-42. Dose and Consequences for the Target Rupture Accident at the Power Burst Facility

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (300 m ESE)	Public Access Location (1000 m S)	Individual Resident (12,400 m SE)	
			All Pathways	External and Inhalation
TEDE (rem)	0.05	0.05	0.0059	0.003
	Collective Impacts to Population within 80 km to the East (Affected Population = 70,150)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	2.2	0.58	16.0	2.7
Fatal Cancers	0.0011	0.00029	0.008	0.0014
Cancer Risk	1×10^{-7}	3×10^{-8}	8×10^{-8}	1×10^{-8}

5.15.4.3 Target Transfer from the Power Burst Facility to Hot Cells

Two bounding accidents were considered during the transfer of the target from the reactor to the hot cells. An accident causing an uncontained target to rupture bounds the risk for offsite residents and population, and direct exposure of a worker to an unshielded target bounds the radiological risk to an involved worker. Other accidents were considered, but the risks and consequences were lower.

The bounding impact for all target transfer operations would be represented by the rupture of a single target as the result of a manned transport accident while in transit between the Power Burst Facility and the nearby hot cell facility. Although highly improbable (estimated probability is less than 1×10^{-6} per year), this accident scenario assumes the loss of all noble gas radionuclides and 1% of halogen radionuclides directly to the atmosphere (Table 5-43). Downwind dose estimates for a cask transport accident between the Power Burst Facility and the INEL hot cell facility are presented in Table 5-43. It was assumed that rupture occurs after a 21-kW, 7-day irradiation, and that all of the noble gases and 1% of the halogens were immediately released from one target into the atmosphere at ground level. The maximum public individual dose from a Mo-99 target transfer accident would be 50 mrem for a resident located 12,400 m (7.7 mi) from the Power Burst Facility. The limiting MEI organ dose would be 1.5 rem to the thyroid with ingestion and 26 mrem without ingestion. This would result in less than 1 (0.07) latent cancer fatality if the accident occurs. This would translate to an average annual accident risk of 7×10^{-9} or the chance of any individual dying of cancer from a target transfer accident is about 1 in 100 million per year of operation.

Table 5-43. Dose and Consequences for the Accidental Release from Target Rupture at INEL Power Burst Facility During Mo-99 Target Transfer

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (200 m S)	Public Access Location (1000 m S)	Individual Resident (12,400 m SE)	
			All Pathways	External and Inhalation
TEDE (rem)	4.8	0.32	0.05	0.0047
	Collective Impacts to Population within 80 km to the East (Affected Population = 70,150)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	17.0	0.75	140.0	7.3
Fatal Cancers	0.085	0.000088	0.07	0.037
Cancer Risk	9×10^{-8}	9×10^{-11}	7×10^{-9}	4×10^{-9}

Due to the extremely high speeds and the impact severity necessary to breach the transportation cask, it is assumed the worker who would be driving the transport vehicle would likely be killed by the impact of the mobile transport accident. The immediate fatality of the worker(s) involved in the transportation accident would bound the risk of the worker dying from a fatal cancer due to any dose received from the accident. Therefore, the dose to the worker was not estimated.

The risk to an involved worker would be identical to that discussed in Section 5.15.1.4 for the worker's direct exposure to the target. The total dose received by the worker would be about 30 rem.

5.15.4.4 Target Processing

Accidents evaluated for analysis during target processing included a fire, target process spill, and release of process gases. The probability of a fire and a process spill, as well as the respective potential doses from these accidents, was much smaller than the probability and consequences from an operator inadvertently opening process valves, sending noble gases up the hot cell facility stack. Thus, the operator error scenario was chosen to bound the risks from other accidents.

The bounding target processing accidents described in Section 5.15.1.5 were developed for the Chemistry and Metallurgy Research Facility and are applied to the Power Burst Facility hot cells as a

bounding case. The release for the Mo-99 production accident is the same as is shown in Table 5-26, and releases for iodine-125 target process accidents are assumed to be the same as described in Section 5.15.1.5. The dose and consequences are shown in Tables 5-44 and 5-45. The maximum public individual dose from a Mo-99 target processing accident would be 0.6 mrem for a resident located 12,400 m (7.7 mi) from the hot cells. The limiting MEI organ dose would be 0.021 mrem to the lung. This accident would result in less than 1 (5.5×10^{-4}) latent cancer fatality if the accident occurs. This number translates into an average annual accident risk of 6×10^{-5} or the chance of latent cancer fatalities in the population from a Mo-99 target processing accident is about 1 in 200,000 per year of operation.

The maximum public individual dose from a iodine-125 target processing accident would be 5.9 mrem for a resident located 12,400 m (7.7 mi) from the INEL hot cells. The limiting MEI organ dose would be 200 mrem to the thyroid with ingestion and 0.36 without ingestion. This accident would result in less than 1 (0.0006) latent cancer fatality if the accident occurs. This figure translates into an average annual accident risk of 6×10^{-6} or the chance of any individual dying of cancer from a iodine-125 target processing accident is about 1 in 200,000 per year of operation.

Table 5-44. Dose and Consequences for the Accidental Release of Noble Gases from INEL Hot Cells During Mo-99 Target Processing

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (200 m S)	Public Access Location (1000 m S)	Individual Resident (12,400 m SE)	
			All Pathways	External and Inhalation
TEDE (rem)	0.062	0.023	0.0006	0.0006
Collective Impacts to Population within 80 km to the Southeast (Affected Population = 70,150)				
Median Atmospheric Dispersion			Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	0.082	0.082	1.1	1.1
Fatal Cancers	0.000041	0.000041	0.00055	0.00055
Cancer Risk	4×10^{-5}	4×10^{-5}	6×10^{-5}	6×10^{-5}

Table 5-45. Dose and Consequences for the Accidental Release of Noble Gases from INEL Hot Cells During Iodine-125 Target Processing

Dose and Consequences	Individual Impacts - Onsite and Offsite			
	Onsite Worker (200 m S)	Public Access Location (1000 m S)	Individual Resident (12,400 m SE)	
			All Pathways	External and Inhalation
TEDE (rem)	0.0015	0.00062	0.0059	0.000031
	Collective Impacts to Population within 80 km to the East (Affected Population = 70,150)			
	Median Atmospheric Dispersion		Bounding Atmospheric Dispersion	
	All Pathways	External and Inhalation	All Pathways	External and Inhalation
Collective TEDE (person-rem)	0.38	0.0062	1.2	0.40
Fatal Cancers	0.00019	0.0000031	0.0006	0.00021
Cancer Risk	2×10^{-5}	3×10^{-7}	6×10^{-6}	2×10^{-6}

5.15.5 Nonradiological Accidents

Nonradiological accidents might consist of the release of toxic or other hazardous materials to the environment, or of physical trauma during construction or operation of facilities. Both types of events are considered in this section

Substantial releases of hazardous or toxic materials to the environment would generally not be expected during operation of the facilities for medical isotope production because of the relatively small quantities of these materials involved in any of the processes. A previous evaluation determined that hypothetical accidents involving hazardous or toxic materials could produce hazardous concentrations of such compounds only in the immediate vicinity of the accident scene (Massey et al. 1995). In that analysis, concentrations of hazardous chemicals that might produce life-threatening or irreversible health effects would not occur beyond a distance of 100 m (328 ft), and concentrations that might produce less severe, temporary health effects would not occur beyond a distance of 300 m (984 ft). Concentrations that might cause transient irritation or a noticeable objectionable odor would not occur beyond a distance of 1000 m (3280 ft). Because these hypothetical releases typically involved spills of concentrated acids or other corrosive solutions, their effect would not be expected to be immediate, even in proximity to the spill, unless the release occurred during an explosion or fire. Therefore, it would be likely that nearby workers or other personnel would have some opportunity to take protective action. The medical isotope production processes and the quantities of hazardous chemicals needed would be similar at all of the facilities; therefore, the potential for major accidents involving toxic or hazardous chemicals are unlikely at any of the candidate sites.

Statistical estimates for industrial accidents during construction and operation of DOE facilities indicate that 1 fatality might be expected for every 9100 worker-years of construction activities or 31,000 worker-years of normal facility operation. The corresponding estimates for occupational injuries and illnesses are 1 for every 16 worker-years of construction or 31 worker-years of normal operations (DOE 1995b). Because of the limited construction activities associated with any of the alternatives considered in this FEIS, no fatalities would be expected; the labor requirements for operation are also sufficiently small so no fatalities would be anticipated for any reasonable duration of the project. Estimates of occupational injuries or illnesses as a result of construction amount to 6 to 7 per year at all sites. Normal operations might result in up to two occupational injuries or illnesses at any site (Table 5-46).

5.15.6 Secondary Impacts of Accidents

Secondary impacts of nonradiological accidents would likely not be extensive because the opportunity for major environmental contamination would be extremely small. The consequences of the accidents would consist of costs for cleanup, treatment, and disposal of hazardous materials. They also could result in temporary suspension of activities at isotope production facilities until the hazardous materials are contained.

Secondary impacts of radiological accidents have been evaluated qualitatively for this analysis. Although the levels of environmental contamination for specific accidents were not assessed directly, the dose to the offsite MEI provides a measure of the air concentration and radionuclide deposition at the site boundary. Therefore, the dose can be used as a semi-quantitative estimate of the level of environmental contamination from a given accident.

Table 5-46. Operational Injuries, Illnesses, and Fatalities for Facility Construction and Operation

	Labor (Worker-Years)		Industrial Accidents ^(a)			
			Injuries and Illnesses		Fatalities	
	Construction	Operations	Construction	Operations	Construction	Operations
SNL/NM	92	59	6	2	0.010	0.0019
LANL	92	45	6	1	0.010	0.0014
ORNL	113	62	7	2	0.012	0.0020
INEL	97	59	6	2	0.011	0.0019

(a) The following rates were assumed to apply to construction and operation of DOE facilities (DOE 1995b Vol. 2, Table F-4-7).

<u>Consequence Rates per Worker-Year</u>	<u>Construction</u>	<u>Operations</u>
Injury / Illness	0.062	0.032
Accidental Fatality	0.00011	0.000032

Accidents that result in estimated doses of less than 0.5 rem to the MEI would likely have few secondary impacts because the levels of offsite environmental contamination in these cases would be relatively small. Protective action guidelines would not require mitigating actions such as evacuation of residents surrounding the site or interdiction of food crops. However, in practice surveys of food and forage grown in the nearby area would likely be conducted to ensure the public and commercial agricultural operations that food products were safe for consumption. Other secondary impacts might include unavailability of facilities and costs for cleanup of contaminated facilities and surrounding areas within the affected site boundary.

Accidents that exceed estimated doses of 0.5 rem to the MEI would have some secondary impacts, with their extent and severity depending on the expected levels of environmental contamination. Protective action guidelines would require mitigating actions, such as evacuation of residents surrounding the site or interdiction of food crops depending on the nature and location of the accident. Other secondary impacts could include

- local (onsite) effects on individual members of some sensitive biota or ecosystems
- temporary closure of recreational and scenic areas, shorelines, and other affected lands (including restrictions on traditional fishing rights and recreational use of rivers for boating or fishing)
- temporary local restrictions on use of affected water supplies for domestic purposes
- possible loss of agricultural crops
- temporary restrictions on land use for agricultural purposes
- costs and exposure to workers associated with cleanup of facilities and environmental contamination
- temporary unavailability of facilities for production of medical isotopes, and possible temporary closure of nearby facilities.

5.16 Cumulative Impacts

The cumulative impacts of the proposed actions in conjunction with other past, ongoing, and reasonably foreseeable actions at the candidate sites are evaluated in this section. Cumulative impacts of the proposed action with other actions were considered to account for the possibility that consequences from several smaller activities might be significant when taken together, whereas the impacts of the individual activities were not. Categories of consequences associated with the proposed alternatives, that were not previously identified as having impacts, are not discussed further with regard to their cumulative effects.

5.16.1 Annular Core Research Reactor: Sandia National Laboratories/New Mexico and the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

Activities identified for the SNL/NM and surrounding region that may contribute to cumulative environmental impacts include ongoing operations and future waste management activities at the laboratory (Massey et al. 1995).

5.16.1.1 Site Services and Resource Use

Consumption of 225 kWh of electricity at SNL/NM during the construction period, or use of about 400 MWh/yr for operation of the facilities, represents a small increase (less than 0.2%) in the site's annual consumption of electricity.

l Increase in water use in the Albuquerque region is considered as one of the potential consequences in
l this EIS. SNL/NM obtains its water from onsite wells at KAFB, supplemented by water purchased from
l the Albuquerque municipal water system. The total water use from operation of the ACRR at SNL/NM
l would increase from the current average of 5000 gal/d to 29,000 gal/d (Section 5.1.13), compared to total
l water use at SNL/NM of 1,000,000 gal/d. This represents less than 3% increase in water use at SNL/NM,
l or 0.03% increase in water use for the region, and would not be expected to substantially impact
l availability or quality of water in the aquifer.

Modifications to existing facilities would not require sufficient resources in terms of labor or materials to substantially impact other ongoing projects at the SNL/NM site or in the surrounding region. Operation of the facilities would require relatively small quantities of common laboratory chemicals, which would not be expected to impact their availability for other DOE or commercial enterprises. These resources would only be used in large quantities if that supplier were no longer in production. Consumption of highly enriched uranium for target fabrication or of reactor fuel-grade uranium for the irradiation facilities is also not expected to be a problem in light of the present surplus of these materials available to DOE and the relatively small quantities needed for the isotope production program.

The labor required for construction of facilities at SNL/NM and the workers employed during facility operations at 100% replacement capacity would represent less than 0.1% of the regional work force.

5.16.1.2 Waste Management

l The 49 m³ (1700 ft³) of solid low-level radioactive waste that is expected to be generated during each
year of operating the medical isotope program at 100% of the U.S. replacement capacity represents a 50%
increase in the total quantity of low-level waste generated annually at the SNL/NM site (100 m³ [3500 ft³]).
Disposal of that quantity of waste at the Nevada Test Site would not represent a substantial increase in the
wastes currently managed at that site, which amounted to 460,000 m³ in 1993 (1994b).

5.16.1.3 Air Quality

Radioactive air emissions from the Annular Core Research Reactor and hot cell facilities would increase the dose to the population around the SNL/NM site (from 0.027 person-rem in 1993 to about 13 person-rem/yr), which would result in less than 1 (0.007) latent cancer fatality. That total represents about a 13% increase in the annual public dose from all DOE operations, which amounted to 100 person-rem during 1994. Cumulative doses to the public during the 5-year period from 1990-1994 amounted to about 0.6 person-rem at SNL/NM and 470 person-rem from all DOE operations. The dose to the MEI would increase from 0.002 mrem to 0.17 mrem, although the sitewide receptor may be in a different location from the receptor for the Annular Core Research Reactor and Hot Cell Facilities. However, both the current and projected doses to the offsite resident would be below the EPA 10 mrem/yr standard.

For perspective, the dose from natural background radiation (including radon) to the 610,000 people within 80 km (50 mi) of SNL/NM would be approximately 180,000 person-rem/yr, which would result in an estimated 91 latent fatal cancers. The same population would be expected to experience about 1200 cancer fatalities in a year from all causes.

5.16.1.4 Occupational Health and Safety

Occupational doses at SNL/NM would increase by approximately 22-25 person-rem/year for facility operations and medical isotope shipments, compared to the worker dose levels of 2 person-rem/year at TA-V and about 10 person-rem for the entire site during 1994. That would represent less than a 2% increase in the total occupational dose incurred yearly by DOE workers, which amounted to about 1800 person-rem during 1994.

5.16.2 Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

Actions identified for the LANL and surrounding region that may contribute to cumulative impacts include ongoing operations, construction and operation of the Dual Axis Radiographic Hydrodynamic Test (DARHT) facility, and future waste management activities at the laboratory (DOE 1995i).

5.16.2.1 Site Services and Resource Use

Consumption of electricity at LANL during the construction period would be minimal, and use of about 500 MWh/yr for operation of the facilities, would represent a small increase (less than 0.2%) in the site's annual consumption of electricity. Use of approximately 120,000 m³ per year of water for reactor cooling would represent about 2% of the site's current consumption rate.

Modifications to existing facilities would not require sufficient resources in terms of labor or materials to substantially impact other ongoing projects at the LANL site or in the surrounding region. Operation of the facilities would require relatively small quantities of common laboratory chemicals and highly enriched

uranium for targets and reactor fuel, which would not be expected to impact availability of these materials for other government or commercial uses as discussed in Section 5.16.1.1. The labor required for construction of facilities at LANL and the workers employed during facility operations at 100% replacement capacity would represent less than 0.1% of the regional work force.

5.16.2.2 Waste Management

The 18 m³ (630 ft³) of solid low-level radioactive waste that is expected to be generated during each year of operating the medical isotope program at 100% of the U.S. replacement capacity would represent less than a 1% increase in the total quantity of low-level waste generated annually at the LANL site (5800 m³ [200,000 ft³]). Disposal of that waste would not represent a substantial increase in the quantity of radioactive wastes currently managed at the site, which amounted to 220,000 m³ in 1993 (DOE 1994b).

5.16.2.3 Air Quality

Radioactive air emissions from the Omega West Reactor and hot cell facilities would increase the dose to the population around the LANL site by about 0.7 person-rem/yr from 4 person-rem/yr in 1994, which would result in less than 1 (2×10^{-3}) latent cancer fatality. That total represents about a 0.7% increase in the annual public dose from all DOE operations, which amounted to 100 person-rem during 1994. Cumulative doses to the public during the 5-year period from 1990-1994 amounted to about 13 person-rem at LANL and 470 person-rem from all DOE operations. The dose to the MEI would increase by 0.2 mrem/yr, compared to 5.6 mrem/yr at the current levels, although the affected individuals from Omega West Reactor and the Chemistry and Metallurgy Research facility emissions are at different locations from those for other site emissions. However, both the current and projected doses to the offsite resident would be lower than the EPA 10 mrem/yr standard. Operation of the DARHT facility would likewise not substantially increase the current offsite dose from LANL activities.

For perspective, the dose from background radiation (including radon) to the 250,000 people within 80 km (50 mi) of LANL would be approximately 75,000 person-rem/yr, which would result in an estimated 38 latent fatal cancers. The same population would be expected to experience about 500 cancer fatalities in a year from all causes.

5.16.2.4 Occupational Health and Safety

Occupational doses at LANL would increase from the 1994 level of 180 person-rem/yr by about 10 person-rem/yr. The increase would represent less than 6% of the current annual occupational dose for the site, or 0.6% of the occupational dose for all DOE facilities (1800 person-rem in 1994).

5.16.3 Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory Alternative

Actions identified for the ORNL and the surrounding region that may contribute to cumulative impacts include ongoing operations, future waste management activities at the site, upgrades to existing facilities and site infrastructure, and potential construction of several new research complexes. This construction includes the proposed Uranium-Atomic Vapor Laser Isotope Separation Facility; an Environmental, Life, and Social Sciences Complex; and a Materials, Science, and Engineering Complex. The city of Oak Ridge anticipates construction of new residential and commercial enterprises in addition to a community golf course. A private company is also in the process of constructing a radioactive waste incinerator to the west of the reservation (DOE 1995b).

5.16.3.1 Site Services and Resource Use

Electricity used at ORNL during the construction period would be minimal, and use of about 500 MWh/yr for operation of the facilities, would represent a small increase (about 0.1%) in the site's annual consumption of electricity. Use of approximately 120,000 m³ (3.1 x 10⁷ gal) per year of water for reactor cooling would increase consumption at the site by about 1%.

Modifications to existing facilities would not require sufficient resources in terms of labor or materials to substantially impact other ongoing projects at the ORNL or in the surrounding region. Operation of the facilities would require relatively small quantities of common laboratory chemicals and enriched uranium for targets and reactor fuel, which would not be expected to impact availability of these materials for other government or commercial uses as discussed in Section 5.16.1.1. The labor required for construction of facilities at ORNL and the workers employed during facility operations at 100% replacement capacity would represent less than 0.1% of the regional work force.

5.16.3.2 Waste Management

The 68 m³ (2400 ft³) of solid low-level radioactive waste expected to be generated during each year of operating the medical isotope program at 100% of the U.S. replacement capacity represents less than a 5% increase in the total quantity of solid low-level waste generated annually at the ORNL (6,900 m³ [240,000 ft³] in 1992). Management of that waste would not represent a substantial increase in the quantity of radioactive wastes currently handled at the site. Low-level waste generated from Mo-99 production would be shipped to the Nevada Test Site for disposal, and would not represent a substantial increase in wastes managed at that site (460,000 m³ in 1993) (DOE 1994b).

5.16.3.3 Air Quality

Radioactive air emissions from the Oak Ridge Research Reactor and hot cell facilities would increase the collective dose to the population around the ORNL by 15 person-rem compared to 43 person-rem for the current site operations. At that level, no latent cancer fatalities (2.9 x 10⁻²) would be expected in the

population in the vicinity of the ORNL. That total represents about a 15% increase in the annual public dose from all DOE operations, which amounted to 100 person-rem during 1994. Cumulative doses to the public during the 5-year period from 1990-1994 amounted to about 170 person-rem at Oak Ridge Reservation and 470 person-rem from all DOE operations. The potential increases in public dose from medical isotope production are minimal compared to the 17,000 person-rem estimated for historic Oak Ridge Reservation operations between 1944 and 1987 (DOE 1988). The dose to the MEI would increase by 0.3 mrem over the current levels, although the affected individuals from Oak Ridge Research Reactor and hot cell operations may be at a different location than for other facility operations. However, both the current and projected doses to the offsite resident would be lower than the EPA 10 mrem/yr standard.

For perspective, the dose from natural background radiation (including radon) to the 910,000 people within 80 km (50 mi) of ORNL would be approximately 270,000 person-rem/yr, which would result in an estimated 140 latent fatal cancers. The same population would be expected to experience about 1800 cancer fatalities in a year from all causes.

5.16.3.4 Occupational Health and Safety

Occupational doses at ORNL would increase from the 1994 level of 71 person-rem/yr by at most 25 person-rem/yr. The increase would represent about 35% of the current annual occupational dose for the site, or less than 2% of the occupational dose for all DOE facilities (1800 person-rem in 1994). Production of medical isotopes would not substantially increase the cumulative historic doses to workers at the Oak Ridge Reservation, which were estimated at 19,000 person-rem between 1943 and 1977 (BEIR 1990).

5.16.4 Power Burst Facility/Test Area North: Idaho National Engineering Laboratory Alternative

Actions identified for the INEL and surrounding region that may contribute to cumulative effects include ongoing operations, future waste management activities at the site, planned decontamination and decommissioning of several obsolete facilities, replacement of underground fossil fuel storage tanks, and upgrades of site infrastructure and irradiated nuclear fuel handling facilities at Argonne National Laboratory-West. Planned construction in the region of a new housing development and several commercial facilities would also occur within the foreseeable future (DOE 1995b).

5.16.4.1 Site Services and Resource Use

Electricity used at INEL during the construction period, or use of about 500 MWh/yr for operation of the facilities, represents a small increase (about 0.2%) in the site's annual consumption of electricity. Use of approximately 120,000 m³ (3.1×10^7 gal) per year of water for reactor cooling would increase consumption at the site by less than 2%.

Modifications to existing facilities would not require sufficient resources in terms of labor or materials to substantially impact other ongoing projects at the INEL or in the surrounding region. Operation of the

facilities would require relatively small quantities of common laboratory chemicals and enriched uranium for targets and reactor fuel, which would not be expected to impact availability of these materials for other government or commercial uses as discussed in Section 5.16.1.1. The labor required for construction of facilities at INEL and the workers employed during facility operations at 100% replacement capacity would represent less than 0.05% of the regional work force.

5.16.4.2 Waste Management

The 80 m³ (2800 ft³) of solid low-level radioactive waste that is expected to be generated during each year of operating the medical isotope program at 100% of the U.S. replacement capacity would represent less than a 10% increase in the total quantity of low-level waste generated annually at the INEL (900 m³ [32,000 ft³] projected in 1995). Disposal of that waste would not represent a substantial increase in the quantity of radioactive wastes currently managed at the site, which amounted to 147,000 m³ in 1993 (see Section 4.4.14.2).

5.16.4.3 Air Quality

Radioactive air emissions from the Power Burst Facility and hot cell facilities would increase the dose to the population around the INEL by about 1.2 person-rem compared to 0.3 person-rem for current operations, which would not be expected to result in latent cancer fatalities (7.5×10^{-4}). That total represents about a 1% increase in the annual public dose from all DOE operations, which amounted to 100 person-rem during 1994. Cumulative doses to the public during the 5-year period from 1990-1994 amounted to about 0.5 person-rem at INEL and 470 person-rem from all DOE operations. The dose to the MEI would amount to 0.1 mrem. However, both the current and projected doses to the offsite resident would be lower than the EPA 10 mrem/yr standard.

For perspective, the dose from natural background radiation (including radon) to the 120,000 people within 80 km (50 mi) of INEL would be approximately 36,000 person-rem/yr, which would result in an estimated 18 latent fatal cancers. The same population would be expected to experience about 240 cancer fatalities in a year from all causes.

5.16.4.4 Occupational Health and Safety

Occupational doses at INEL would increase from the 1994 level of 240 person-rem/yr by at most 25 person-rem/yr. The increase would represent about 10% of the current annual occupational dose for the site, or less than 2% of the occupational dose for all DOE facilities (1800 person-rem in 1994).

5.16.5 Cumulative Impacts of Transportation

The cumulative impacts of transportation are similar for shipments from all of the candidate sites, and the majority of the consequences occur during shipments to pharmaceutical suppliers beyond the borders

of the production sites. Annual collective doses to the transport crews would range from 23 to 24 person-rem/yr, those for the public would range from 26 to 53 person-rem, and the combined total would not be expected to result in any latent cancer fatalities for any reasonable duration of the project. The consequences of any of the alternatives would be small compared to estimates of total annual transportation consequences for shipment of radioactive materials, such as those from industrial, medical, and commercial nuclear power facilities -- about 5600 person-rem to transport workers and 4200 person-rem to the general public (a total of 4 estimated latent cancer fatalities per year of such shipments). The impacts of the alternatives evaluated in this EIS would also be lower than the transportation impacts of reasonably foreseeable actions, such as transportation of commercial spent nuclear fuel and DOE high-level defense waste to a geologic repository and disposal of transuranic waste at the Waste Isolation Pilot Plant in Carlsbad, New Mexico. These activities represent a total of up to 11,000 person-rem to workers and 50,000 person-rem to the general population (estimated 29 latent cancer fatalities) for both actions (DOE 1995b).

5.17 Unavoidable Adverse Environmental Impacts

Adverse environmental impacts associated with medical isotope production would be largely due to operation of the reactor and hot cell facilities at full capacity, whereas previously they had been shut down or used intermittently, and from transportation of the separated products to pharmaceutical manufacturers where they are prepared for final distribution to end users. Unless the current supplier of medical isotopes for the U.S. were unable to continue operating, production would be at a fraction of the capacity evaluated in this EIS, and the consequences would be lower than those presented also. If production to meet 100% of the current U.S. demand were required, consequences at the selected site would be larger; however, they would amount to relocation of impacts that are presently occurring to supply U.S. needs from the region adjacent to the Canadian supplier to that surrounding the selected DOE facility.

Modifications to existing facilities that would be necessary to implement the project would not be sufficiently extensive to result in significant excavation or construction, and would occur in previously developed areas of the candidate sites. Therefore, impacts on land use, socioeconomics, cultural resources, aesthetic and scenic resources, geological resources, water quality, ecological resources, community noise levels, and construction resources would be minimal or nonexistent.

5.18 Relationship Between Short-Term Uses of the Environment and the Maintenance and Enhancement of Long-Term Productivity

The alternatives considered in this EIS include use of existing DOE reactors and support facilities to develop a domestic supply of medical isotopes in the event they were not available from the current supplier. Some of the facilities have alternate research missions that require part-time operation; whereas, others are inactive and may eventually be scheduled for decommissioning. Alternate uses for these facilities might include support for other DOE projects, or they could be deactivated and decommissioned.

If the facilities were decommissioned, the land previously occupied by them might be used for construction of other DOE facilities, or it could be reclaimed for other uses.

Because the candidate facilities are part of larger active DOE complexes, release of the land for commercial, residential, recreational, or agricultural purposes appears to be impractical over the short term. Certain types of future use (such as for residential or agricultural purposes) might ultimately be restricted because of possible contamination with radionuclides or hazardous chemicals, or the perception of such contamination. For that reason, use of the candidate facilities to provide a backup source of medical isotopes would not further limit future use of the facilities, or the land on which they stand, beyond the restrictions that already exist.

Upgrading and operating existing facilities for medical isotope production may contribute to their long-term productivity and make possible other missions that would not be viable without cooperative support. Use of the INEL Power Burst Facility for medical cancer therapy is an example of a project that has been proposed in the past and which could be carried out concurrently with the isotope production mission, resulting in cost savings for both programs. Use of the facilities for isotope production would also be compatible with simultaneous use for research in many cases. In addition, refurbishing existing facilities to extend their useful life would result in lower environmental impacts than construction of new facilities either by DOE or by a private enterprise. Therefore, use of existing DOE facilities to provide a backup supply of medical isotopes could be considered an alternative that optimizes both near-term productivity of the facilities and long-term protection of the environment.

5.19 Irreversible and Irretrievable Commitment of Resources

This section addresses the irretrievable commitment of resources that would likely be used to implement the proposed EIS alternatives. Irretrievable use of a resource occurs when a resource is irreplaceably lost and cannot be replenished.

Modifications to existing facilities in order to implement the medical isotope production project would require use of relatively small quantities of construction materials and labor, which would not be likely to impose a burden on regional resources. Operation of the facilities would utilize common laboratory chemicals in modest quantities and enriched uranium for targets and reactor fuel, none of which are in limited supply. These resources would only be consumed in significant quantities if the current isotope supplier were not operating. A comparison of resources needed to implement the alternatives considered in this EIS is listed in Table 5-47.

Table 5-47. Resources Required to Prepare and Operate DOE Facilities for Production of Medical Radioisotopes

Consequence Category	Unit of Measure	Alternatives			
		SNL/NM-ACRR LANL-CMR	LANL OWR/CMR	ORNL ORRR/RDL	INEL PBF/TAN
Resource Use - Construction					
Electricity	kilowatt-hours	230	negligible	4	450
Concrete	cubic meters	1200	0	20	2400
Construction Steel	tonnes	0.21	0	negligible	0.39
Stainless Steel	tonnes	1.0	0.2	3.5	1.5
Resource Use - Operations					
Water	1000 m³/yr	40	120	120	120
Electricity	megawatt-hours/yr	400	500	500	500
Materials - Target Fabrication					
Highly enriched uranium	kg/yr	4-36 ^(a)	3 ^(a)	3-26 ^(a)	3-26 ^(a)
Stainless Steel	tonnes/yr	0.5	0.4	0.4	0.4
Chemicals - Isotope Recovery					
Sulfuric acid, 2N	liters	(b)	120	Same as LANL	
Sulfuric acid, 0.1N	liters		36		
Hydrochloric acid, reagent grade	liters		1.2		
Nitric acid, reagent grade	liters		6		
Sodium hydroxide, 0.2N	liters		24		
Sodium iodide	grams		120		
Silver Nitrate	grams		600		
Benzoin-α-oxime	kilograms		2.4		
Molybdenum trioxide	grams		24		
Potassium permanganate	grams		100		
Rhodium trichloride	grams		24		
Potassium hexachlororuthenate	grams		24		
Hydrogen peroxide	liters		2.4		
Calcium oxide	liters		12		
Calcium sulfate "drierite"	liters		36		
Molecular sieve type 13X	liters		36		

Table 5-47. (contd)

Consequence Category	Unit of Measure	Alternatives			
		SNL/NM-ACRR LANL-CMR	LANL OWR/CMR	ORNL ORRR/RDL	INEL PBF/TAN
Reactor Fuel					
Kilograms of uranium used in fuel	kilograms U/yr	16	32	32	32
Socioeconomics					
<u>Primary Employment</u>					
Construction/modifications	worker-years	92	92	113	97
Routine operations	workers	59	45	62	59
<u>Costs</u>					
Construction/modifications	million dollars	19.6	19.6	21.0 ^(c)	17.2 ^(c)
Routine operations	million dollars	12.8	11.0	9.6 ^(c)	8.4 ^(c)
(a) Minimum values assume 90% recovery of highly enriched uranium after isotope extraction. Uranium recovery would occur at LANL, and could be implemented at other sites. However, consequence analyses presented in other sections do not assume uranium recovery at sites other than LANL.					
(b) Consumption of chemicals for target processing assumes irradiation of targets to a power of 20 kW. At SNL/NM, production rates corresponding to 100% replacement of U.S. needs would likely require processing of a greater number of targets at lower power. In that case, the quantity of chemicals used to process the targets would increase by about 40%.					
(c) As explained in Section 5.22, the cost estimates for ORNL and INEL are expected to contain greater uncertainties than those presented for SNL/NM and LANL.					
ACRR - Annular Core Research Reactor; CMR - Chemistry and Metallurgy Research Facility; OWR - Omega West Reactor; ORRR - Oak Ridge Research Reactor; PBF - Power Burst Facility; RSL - Radioisotope Development Laboratory; TAN - Test Area North.					

5.20 Potential Mitigation Measures

Mitigation measures typically applied to the operation of small research reactors and to the activities necessary to fabricate, irradiate, and process the Mo-99 targets would be applied throughout the project. These measures include filtration of air emissions from target fabrication, irradiation, and processing activities in accordance with applicable requirements and ALARA principles. No impacts were identified for any alternative on land use, cultural resources, geologic resources, ecological resources, community noise levels, socioeconomics, or aesthetic and scenic resources; therefore, mitigation measures for potential impacts in these categories would not be necessary.

5.21 Environmental Justice

As a result of Executive Order 12898 (February 11, 1994), federal agencies are responsible for identifying and addressing the possibility of disproportionately high and adverse environmental impacts of

their programs and activities on minority and low-income populations. This section considers the location of minority and low-income populations surrounding the potential sites for the production of Mo-99 and considers their susceptibility to disproportionately adverse environmental consequences of alternatives considered in this FEIS. Impacts along transportation routes for either routine operations or accidents to even the MEI located at 100 m (328 ft) from the release site are estimated to be insignificant (Section 5.1.1). Because the consequences for any individual of any group from transportation are insignificant, minority and low-income individuals are not considered to be adversely and disproportionately affected along those routes.

For purposes of this analysis, minority populations are defined as all non-white individuals, plus Hispanic whites, as reported in the 1990 census. Low-income persons are defined as living in households in the 1990 Census that reported an annual income less than the U.S. official poverty level. The poverty level varies by size and relationship of the members of the household. It was \$12,674 for a family of four at the 1990 Census. Nationally, in 1990, 24.2% of all persons were minorities and 13.1% of all households had incomes less than the poverty level.

No agreed-upon standard yet exists within the emerging federal guidance on environmental justice for what constitutes an area that has a minority or low-income population large enough to act as a test for disproportionate impact. For example, it has not been decided in the case of minority residents whether the standard ought to be 50% minority residents, more than the national average of minority residents (24.2%), more than the state average, or some other number that takes into account other regional population characteristics. This decision is even more problematic for defining low-income residents, since less income is needed to maintain a given living standard in areas with a relatively low cost of living. Several different definitions have been proposed, but each potential definition has strengths and weaknesses. Therefore, figures in this section employ a graduated shading scheme that indicates those areas of small and roughly equal numbers of housing units that have heavy concentrations of minority and low-income residents, as well as those areas that have lighter concentrations of such residents. Shaded areas generally indicate those census block groups that have higher than the national average percentages of minority and low-income populations, with darker shading showing heavier concentrations.

5.21.1 Annular Core Research Reactor: Sandia National Laboratories/New Mexico and the Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

Figures 5-2 and 5-3 and Table 5-48 show the geographic distribution of minority and low-income population within census block groups (areas defined for monitoring census data of approximately 250 to 550 housing units) that are within 80 km (50 mi) of the Annular Core Research Reactor. The two figures also show the location as the Annular Core Research Reactor. Although target production occurs at LANL under the preferred alternative, no environmental consequences are expected from target production. Thus, the remainder of this section focuses on SNL/NM.

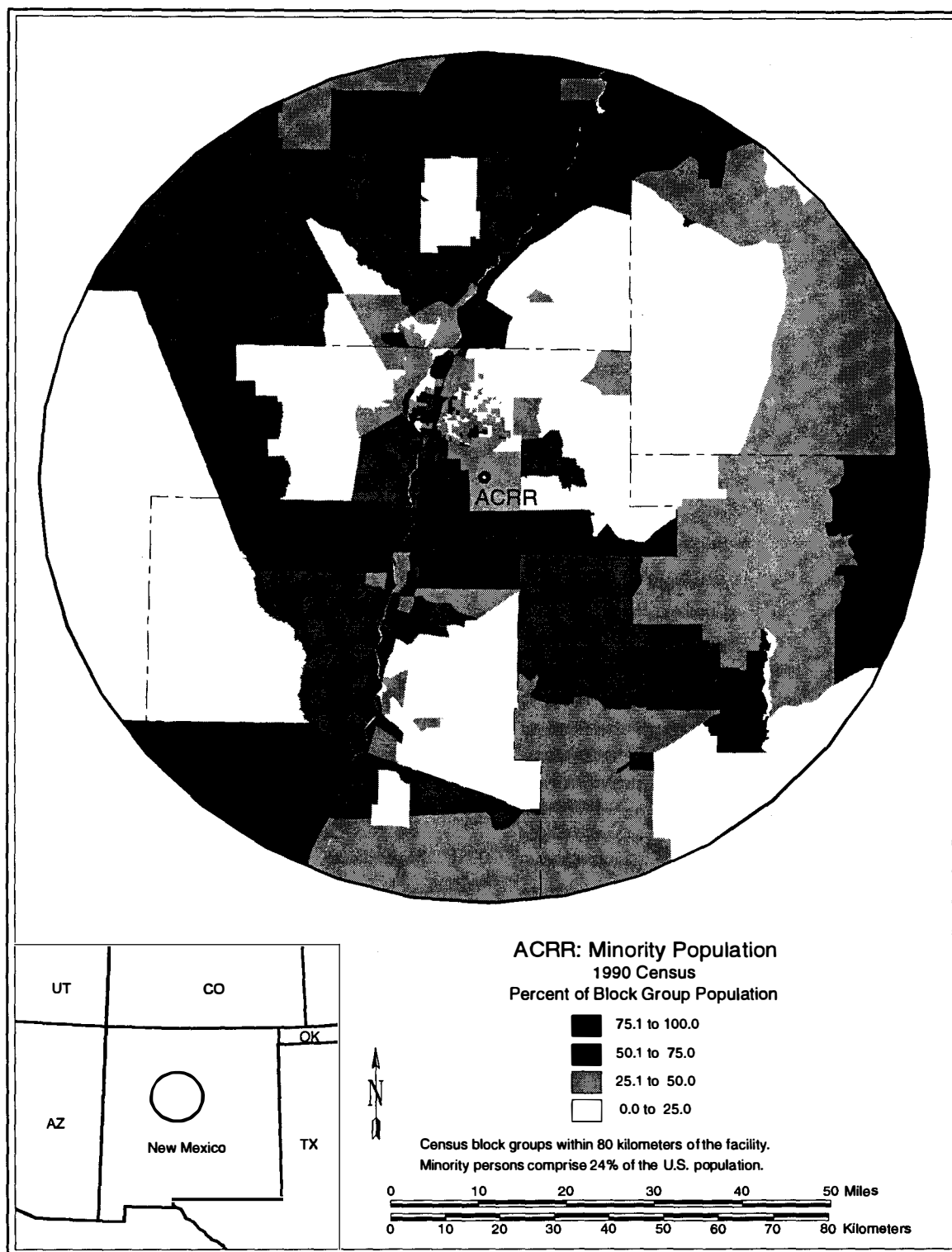


Figure 5-2. Minority Population - Annular Core Research Reactor

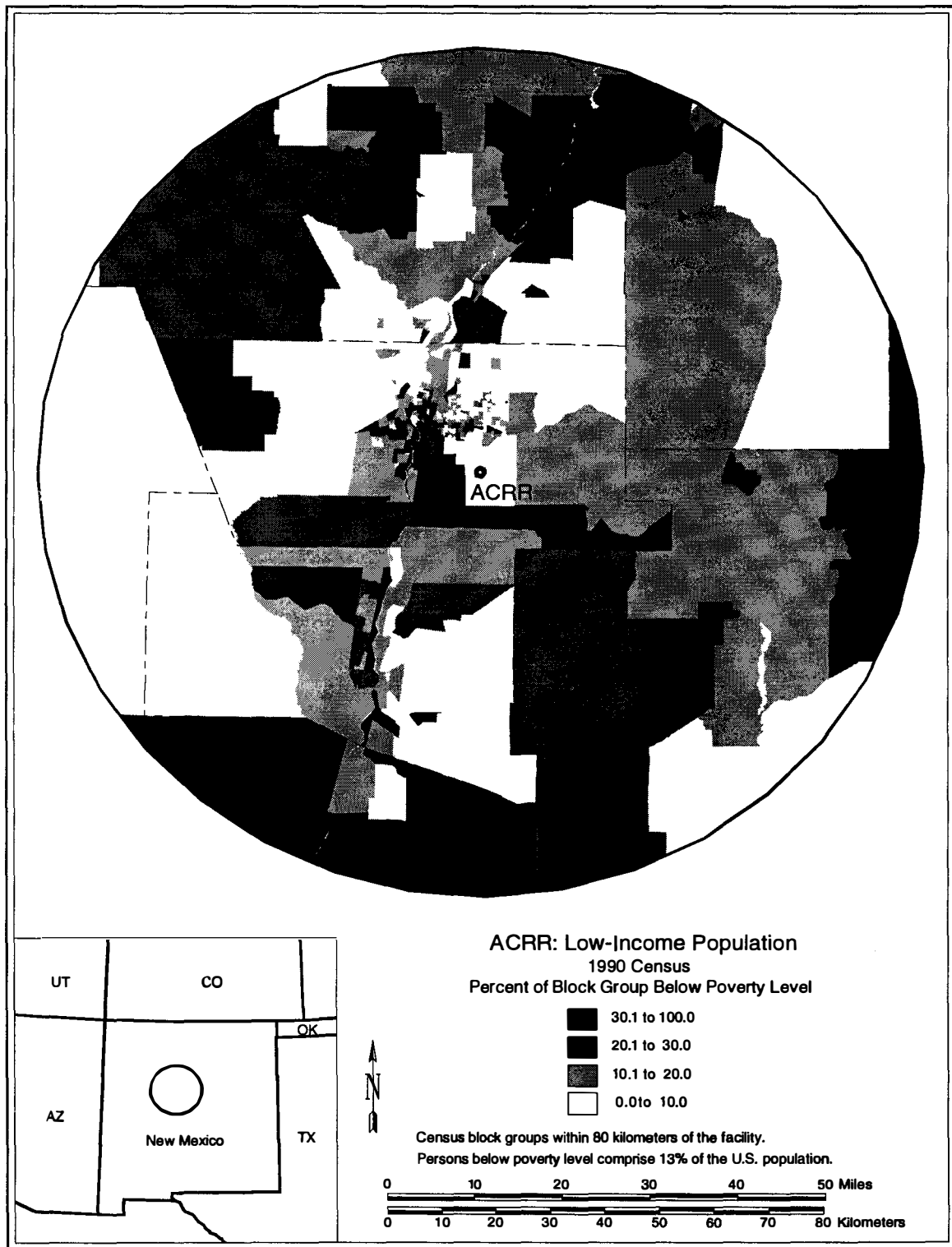


Figure 5-3. Low-Income Population - Annular Core Research Reactor

Table 5-48. Location of Minority and Low-Income Populations Surrounding the Annular Core Research Reactor by Distance and Direction (1990 Census Data)

	Total Minority Population			Low-Income Persons		
	0-16 km (0-10 mi)	16-48 km (10-30 mi)	48-80 km (30-50 mi)	0-16 km (0-10 mi)	16-48 km (10-30 mi)	48-80 km (30-50 mi)
N	70,445	39,274	362	7,657	3,346	1,130
NNE	37,051	6,182	3,303	3,717	328	1,606
NE	3,211	4,656	3,689	245	324	524
ENE	745	4,915	557	98	525	81
E	735	5,053	740	104	844	165
ESE	723	1,778	1,280	105	449	279
SE	534	490	742	71	153	177
SSE	359	384	1,049	57	121	439
S	308	1,105	590	53	336	230
SSW	310	16,295	2,691	59	4,551	637
SW	222	15,643	74	86	3,249	43
WSW	1,865	703	16	494	328	0
W	6,199	3,843	21	1,746	1,069	62
WNW	13,676	16,435	16	6,238	5,752	327
NW	34,730	40,611	21	13,335	7,330	8
NNW	59,944	62,741	143	12,442	6,524	728
Total, 0-80 km (0-50 mi)			466,316			87,444

Figure 5-2 and Table 5-48 together indicate the largest numbers of minority populations are located to the northwest to northeast, and highest concentrations of minority populations generally are located west, southwest, west southwest, and south of the Annular Core Research Reactor, with several pockets at a greater distance, beyond 48 km (30 mi) from the Annular Core Research Reactor. The more concentrated minority populations to the south and west are residents of the Isleta, Laguna, and Acoma Pueblos, and of Canoncito (a land grant). Lighter scatterings of minority populations are located to the north (including the Sandia Pueblo, north of Albuquerque) and east, and still other pockets of minorities at greater distances. Figure 5-3 shows that low-income residents are similarly distributed, with high concentrations of poverty-level households to the southwest and west southwest of the Annular Core Research Reactor.

Although some minority and low-income populations live relatively close to the Annular Core Research Reactor, Sections 5.7 and 5.8 indicate it is very unlikely that routine operations would affect

them with radiological and non-radiological health impacts and other risks. These risks would be insignificant for any offsite population for any alternative discussed in this section. Therefore, it is unlikely that any minority or low-income population would be disproportionately affected by routine operations of either of the process variations at the Annular Core Research Reactor.

While very unlikely, some worst-case accident scenarios, the effects of which are described in Section 5.15, could result in significant air releases of radionuclides that, in turn, could slightly affect some offsite populations (up to 1 fatal cancer within 80 km [50 mi] of the facility). Whether the effect on minority and low-income residents would be disproportionate would depend very much on atmospheric conditions (especially wind directions) at the time of such a release. Prevailing winds are from the north, while most of the concentrations of minority- and low-income areas are located to the south and west of the KAFB. However, the wind blows from the south, southeast, or east southeast about one-third of the time (Appendix D). Winds from the north, northwest, or west northwest would carry any airborne release to the south, southeast, or east southeast. A small, but still potentially disproportionate, number of minority and low-income persons could be affected in the event of rarer northeasterly and easterly winds, depending on the exact wind direction and speed. (However, the closest community to the Annular Core Research Reactor is Four Hills, a middle- to upper-income nonminority community, with the next closest community being mixed low-to-middle income housing at KAFB.) The maximum reasonably foreseen impact scenario for an accident discussed in Section 5.15 is one in which the wind is from the south and carries an airborne release over Albuquerque to the immediate north of the Annular Core Research Reactor. In that case, the higher-income majority population is more likely to be disproportionately affected.

No reasonably foreseen water-related radiological accident identified in Section 5.15 has any significant consequences for any downstream population or source of groundwater, so it is unlikely that minority or low-income populations would be adversely and disproportionately affected through this pathway.

Radiological accidents that exceed 0.5 rem to the MEI could have some secondary impacts due to environmental contamination and mitigative actions under protective action guidelines (Section 5.15). These secondary impacts could include loss of access to crops and possible loss of some agricultural crops and loss of income by minority and low-income farm workers. It is not clear whether such impacts would be disproportionate.

Non-radiological accidental releases would not cause impacts at the nearest point of public access (Section 5.15). No reason exists for minorities and low-income persons to be disproportionately affected.

5.21.2 Omega West Reactor/Chemistry and Metallurgy Research Facility: Los Alamos National Laboratory Alternative

Figures 5-4 and 5-5 and Table 5-49 show the geographic distribution of minority and low-income population within census block groups (areas defined for monitoring census data of approximately 250 to 550 housing units) that are within 80 km (50 mi) of the Omega West Reactor. The two figures also show the location of the Omega West Reactor.

Figure 5-4 and Table 5-49 together indicate the largest numbers and heaviest concentrations of minority populations generally are located to the immediate west northwest to east northeast and west southwest to east southeast of the Omega West Reactor facility at distances between 0 and 48 km (0 and 30 mi). Several close-in Pueblos occupied by Native Americans are located southwest, west southwest, and south of the Omega West Reactor facility, with several pockets of minorities at a greater distance) beyond 48 km (30 mi) from the Omega West Reactor facility. Lighter scatterings of minority populations are located to the north and east. Figure 5-5 shows that low-income residents are similarly distributed, with the largest numbers and highest concentrations to the west, north, and east of the facility.

Although some minority and low-income populations live relatively close to the Omega West Reactor facility, Sections 5.7 and 5.8 indicate it is very unlikely that routine operations would affect them with radiological and non-radiological health impacts and other risks. These risks would be insignificant for any offsite population for any alternative discussed in this section. Therefore, it is unlikely that any minority or low-income population would be disproportionately affected by routine operations at the Omega West Reactor facility.

At Omega West Reactor facility, a fuel melt-related release could result in significant air or water releases of radionuclides that, in turn, could slightly affect any offsite populations (less than one fatal cancers within 80 km [50 mi] of Omega West Reactor) (Section 5.15). Whether the effect on minority and low-income residents would be disproportionate would depend very much on atmospheric conditions (especially wind directions) at the time of such a release. The maximum reasonably foreseen accident has the emission plume drifting to the northwest. The prevailing wind at Omega West Reactor is from the west (Appendix D). The wind blows from the west over half of the time. Only rarely does it blow from the northeast (where the pueblos would be affected in the event of a release) or from the south or southeast (affecting minority groups to the north and northwest). Most of the concentrations of minority and low-income areas are located to the north and east. Therefore, disproportionate impacts on minorities and low-income persons are likeliest when the wind is from the south, southeast or southwest. However, this direction from the Omega West Reactor includes the city of Los Alamos, which contains an overwhelmingly high-income majority population. Thus, it is unlikely that minority or low-income populations would be disproportionately affected.

No reasonably foreseen water-related radiological accident in Section 5.15 has any significant consequences for any downstream population, including recreationists near the Omega West Reactor and

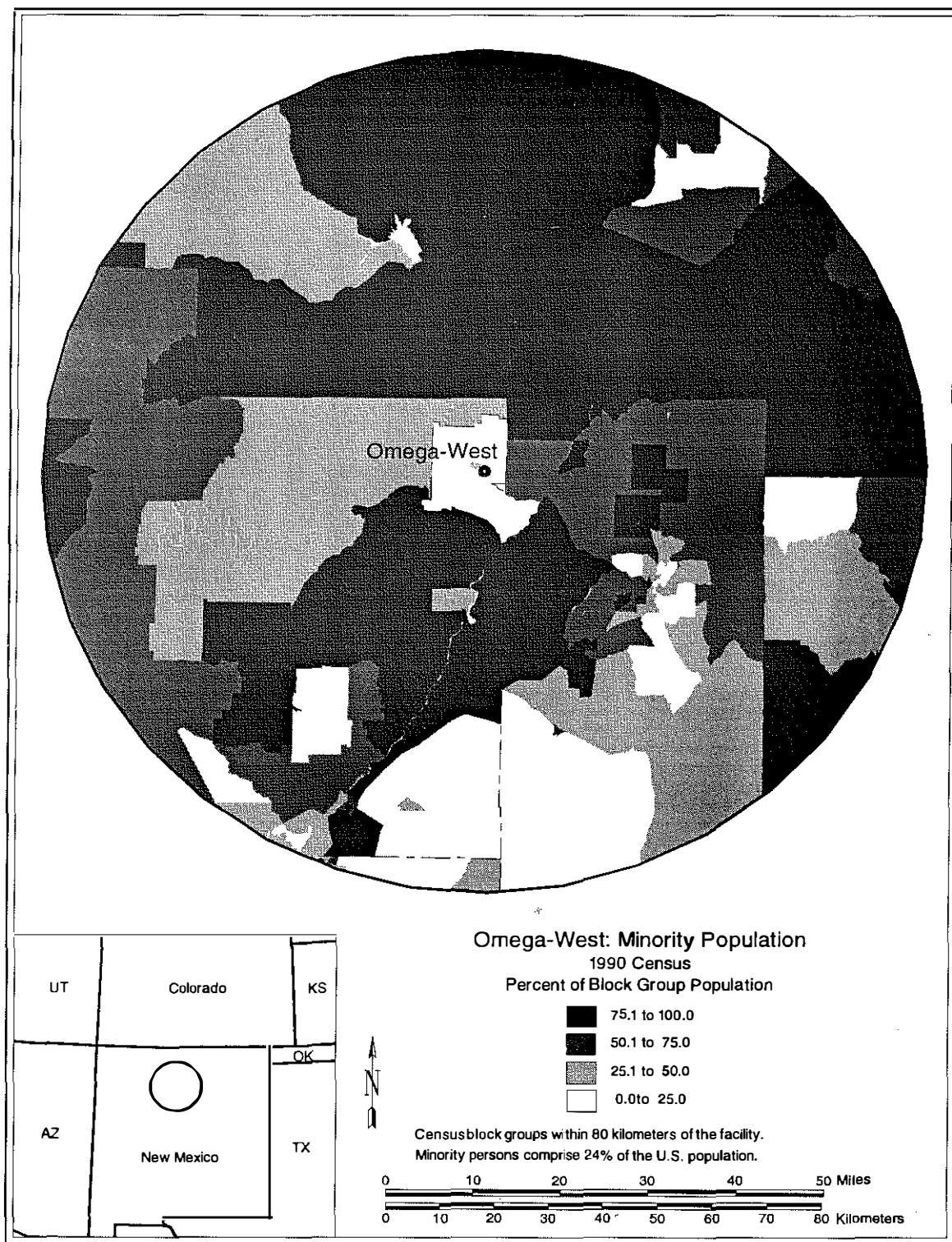


Figure 5-4. Minority Population - Omega West Reactor

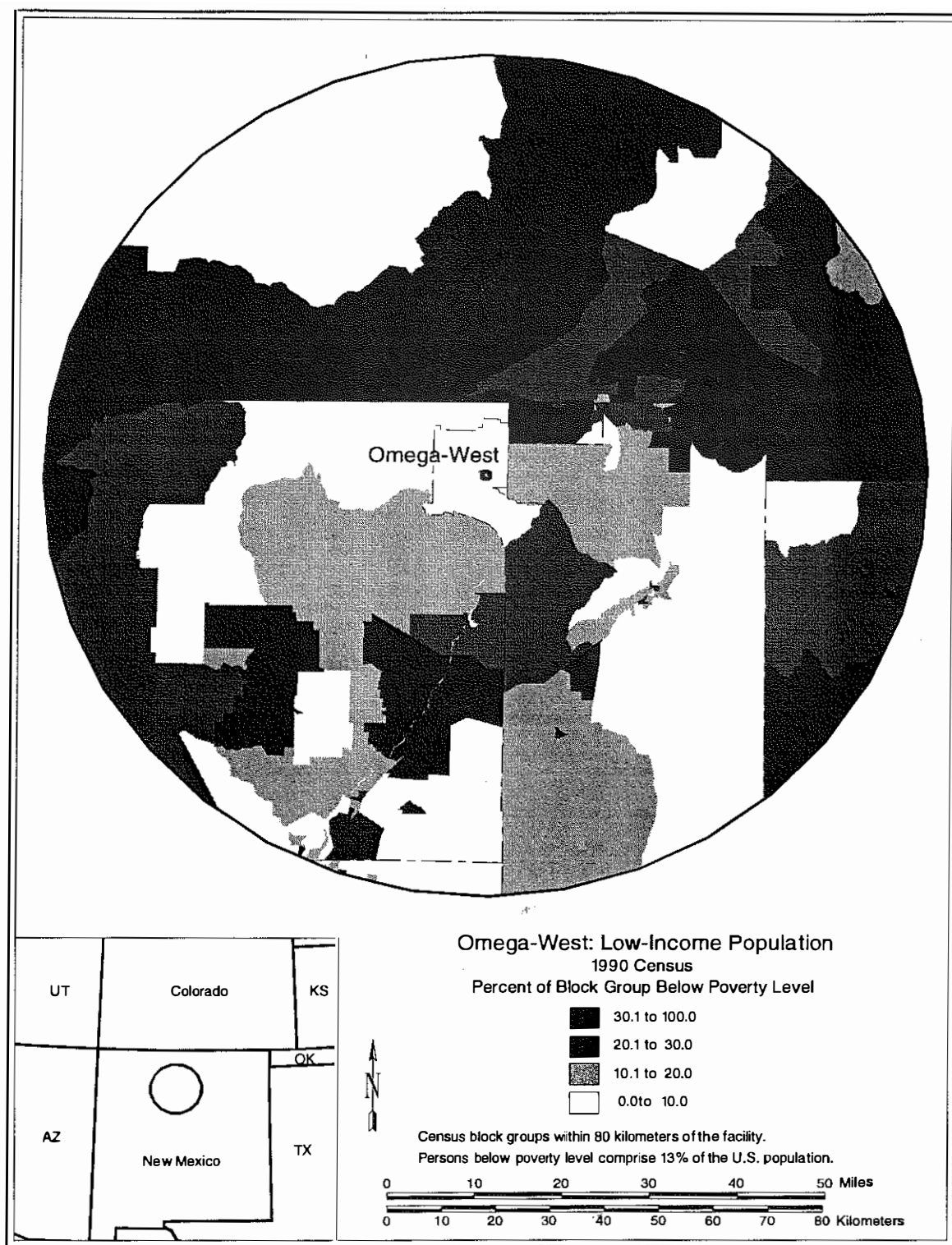


Figure 5-5. Low-Income Population - Omega West Reactor

Table 5-49. Location of Minority and Low-Income Populations by Distance and Direction from Omega West Reactor (1990 Census Data)

	Total Minority Population			Low Income Persons		
	0-16 km (0-10 mi)	16-48 km (10-30 mi)	48-80 km (30-50 mi)	0-16 km (0-10 mi)	16-48 km (10-30 mi)	48-80 km (30-50 mi)
N	939	746	539	47	343	225
NNE	883	1,335	553	90	484	226
NE	703	10,085	4,171	123	3,552	1,817
ENE	975	11,145	2,144	61	2,997	1,011
E	954	2,501	825	74	460	399
ESE	1,165	9,987	2,192	100	978	620
SE	4,324	47,943	3,798	85	7,458	384
SSE	419	3,809	1,591	10	862	231
S	147	537	4,152	5	761	385
SSW	161	366	37,312	3	871	4,188
SW	290	68	204	4	265	473
WSW	433	792	75	11	130	226
W	466	321	63	14	48	335
WNW	1,668	82	1,259	54	62	637
NW	3,209	100	309	77	110	53
NNW	1,091	189	246	41	139	27
Total, 0-80 km (0-50 mi.)			167,018			31,528

sources of ground water, so it is unlikely that minority or low-income populations would be disproportionately affected through this pathway.

Radiological accidents that exceed 0.5 rem to the MEI could have some secondary impacts due to environmental contamination and mitigative actions under protective action guidelines (Section 5.15). These secondary impacts could include loss of access to the pueblos for Native American populations, as well as possible loss of some agricultural crops and loss of income by minority and low-income farm workers. It is unclear whether such impacts would be disproportionate.

Non-radiological accidental releases would not impact the nearest point of public access (Section 5.15). No reason exists for minorities and low-income persons to be disproportionately affected.

5.21.3 Oak Ridge Research Reactor/Radioisotope Development Laboratory: Oak Ridge National Laboratory Alternative

Figures 5-6 and 5-7 and Table 5-50 show the geographic distribution of minority and low-income population within census block groups (areas defined for monitoring census data of approximately 250 to 550 housing units) that are within 80 km (50 mi) of the Oak Ridge Research Reactor. The two figures also show the location of the Oak Ridge Research Reactor.

Figure 5-6 and Table 5-50 together indicate the largest numbers and highest concentrations of minority populations generally are located immediately to the northeast of the facility in the city of Oak Ridge with one further small pocket at a greater distance in Knoxville and beyond 48 km (30 mi) from the Oak Ridge Research Reactor. Figure 5-7 shows that low-income populations are much more prevalent, with one pocket in the city of Oak Ridge, and significant low-income areas generally lying to the northwest at 16 to 48 km (10 to 30 mi) distance. Lighter scatterings of minority populations are located to the east and southeast.

Although some minority and low-income populations live in relatively close proximity to the Oak Ridge Research Reactor, Sections 5.7 and 5.8 indicate it is very unlikely that routine operations would affect them with radiological and non-radiological health impacts and other risks. These risks would be insignificant for any offsite population for any alternative discussed in this section. Therefore, it is unlikely that any minority or low-income population would be disproportionately affected by routine operations of the Oak Ridge Research Reactor

A fuel melt accident scenario, the effects of which are described in Section 5.15, could result in significant air releases of radionuclides that, in turn, could affect some offsite populations (up to 6 fatal cancers within 80 km [50 mi] of the Oak Ridge Research Reactor). Whether the effect on minority and low-income residents would be disproportionate would depend on atmospheric conditions (especially wind directions) at the time of such a release. The only close concentrations of minorities areas are located to the north and east. Therefore, significant impacts on minorities and low-income persons are most likely when the wind is from the southwest, a reasonably common occurrence at Oak Ridge (Appendix D). Indeed, the maximum reasonably foreseen accident shows the emissions plume drifting to the east. However, this direction from the Oak Ridge Research Reactor includes the area of West Knoxville, which also contains several high-income and majority populations. Thus, it is uncertain whether minority or low-income populations would be disproportionately affected.

No reasonably foreseen water-related radiological accident has been identified for the Oak Ridge Research Reactor (Section 5.15), so it is unlikely that minority or low-income populations would be adversely and disproportionately affected through this pathway.

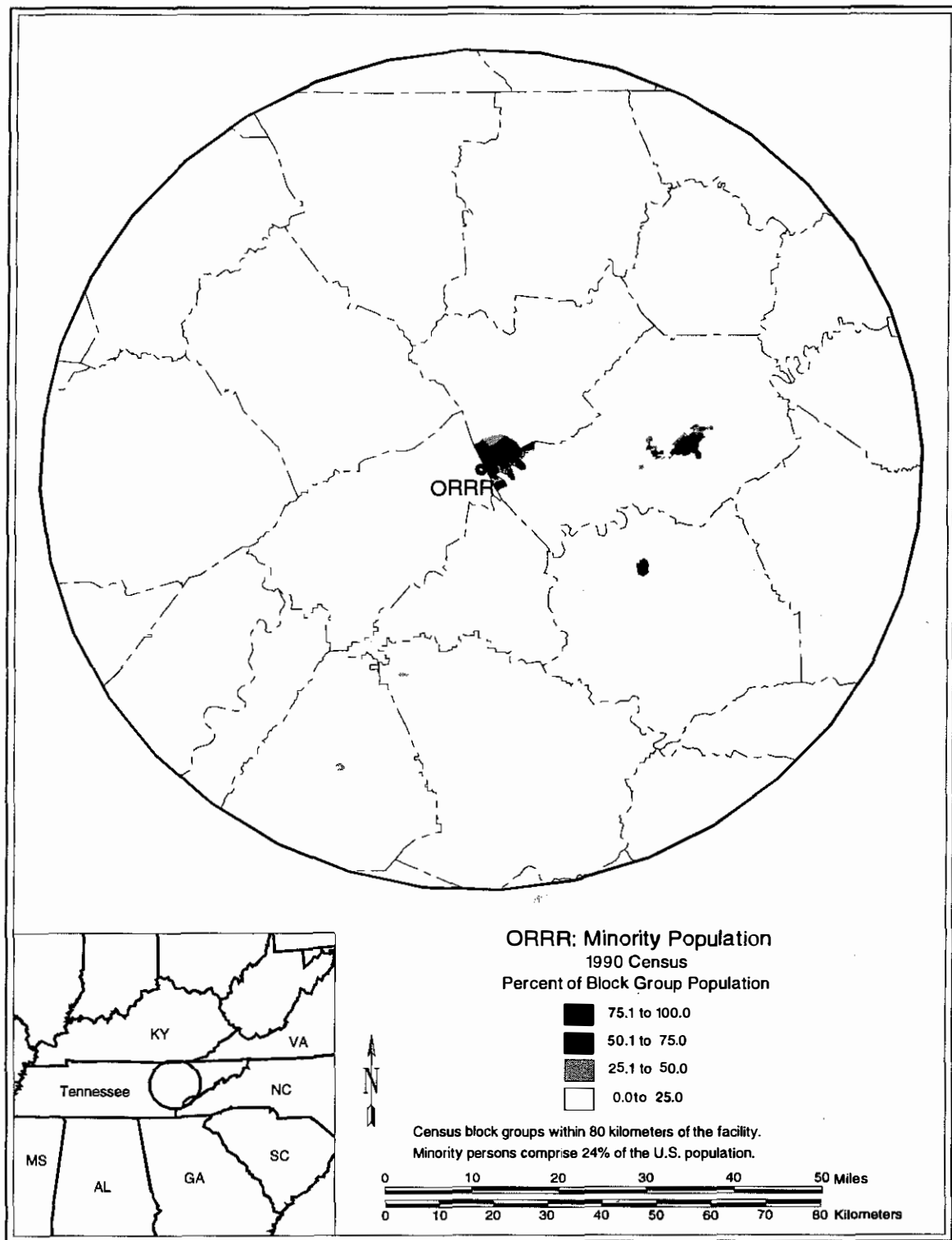


Figure 5-6. Minority Population - Oak Ridge Research Reactor

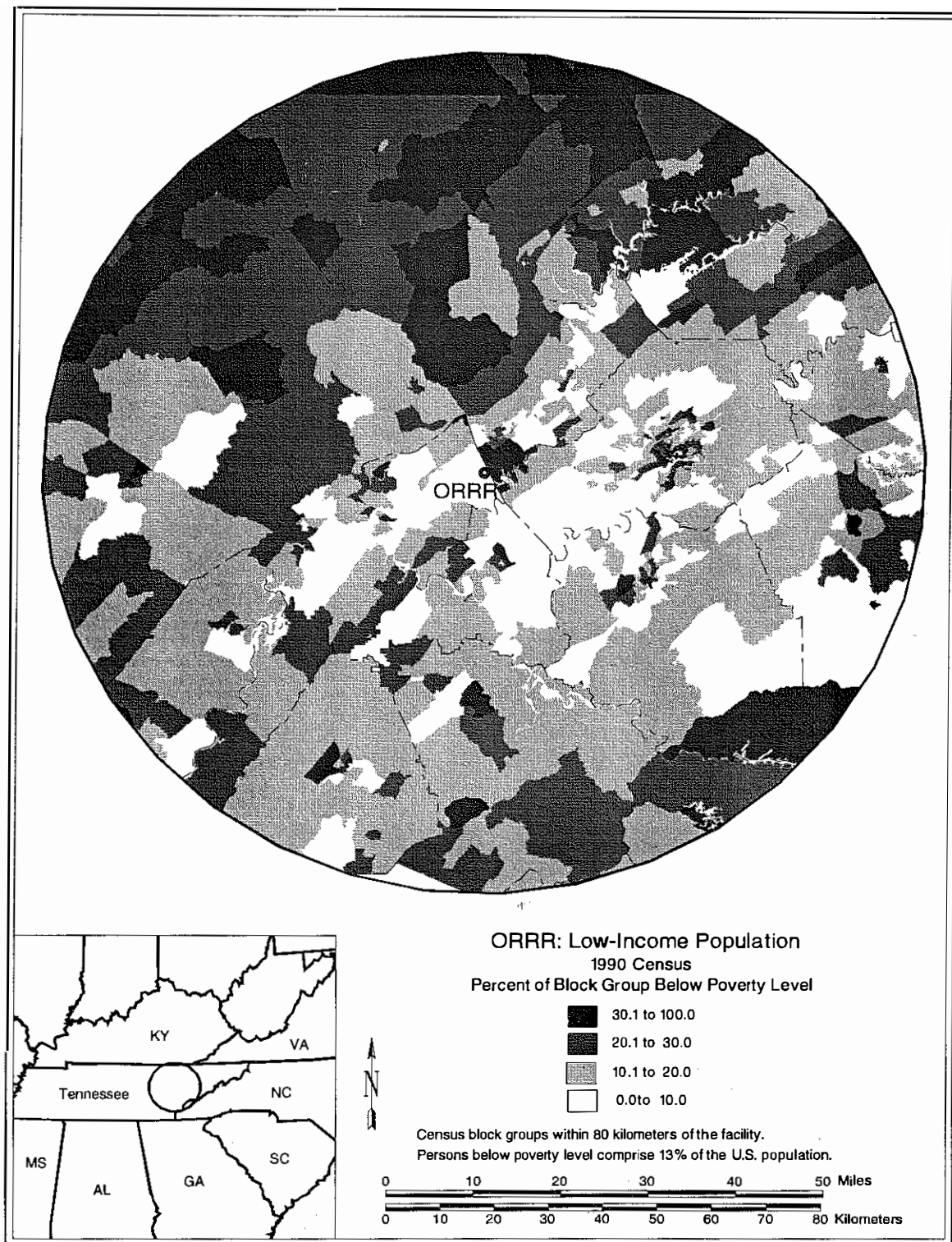


Figure 5-7. Low-Income Population - Oak Ridge Research Reactor

Table 5-50. Location of Minority and Low-Income Populations Surrounding the Oak Ridge Research Reactor by Distance and Direction (1990 Census Data)

	Total Minority			Low-Income Persons		
	0-16 km (0-10 mi)	16-48 km (10-30 mi)	48-80 km (30-50 mi)	0-16 km (0-10 mi)	16-48 km (10-30 mi)	48-80 km (30-50 mi)
N	5,714	2,762	7,932	714	652	3,096
NNE	11,944	20,390	23,125	1,787	3,993	7,117
NE	7,700	26,877	12,524	605	3,987	2,946
ENE	3,892	87,529	32,984	504	9,669	5,225
E	3,140	153,333	41,396	337	31,958	5,562
ESE	8,368	61,800	20,347	548	5,338	2,563
SE	8,352	38,279	2,391	255	4,805	486
SSE	4,407	10,582	3,085	302	1,357	707
S	2,967	19,356	13,227	445	3,142	2,477
SSW	1,152	13,519	35,396	142	2,151	6,504
SW	1,276	6,251	15,675	119	936	2,569
WSW	1,832	20,094	9,880	134	3,393	1,792
W	1,549	12,493	25,170	106	2,758	4,473
WNW	1,667	5,896	7,597	223	1,032	1,967
NW	1,984	6,444	10,405	305	1,093	3,527
NNW	3,921	2,141	14,494	582	551	4,035
Total, 0-80 km (0-50 mi)			818,745			134,933

Radiological accidents that exceed 0.5 rem to the MEI could have some secondary impacts due to environmental contamination and mitigative actions under protective action guidelines (Section 5.15). These secondary impacts could include possible loss of some agricultural crops and loss of income by minority and low-income farm workers. It is unclear whether such impacts would be disproportionate.

Non-radiological accidental releases would not cause impacts at the nearest point of public access (Section 5.15). No reason exists for minorities and low-income persons to be disproportionately affected.

5.21.4 Power Burst Facility/Test Area North: Idaho National Engineering Laboratory Alternative

Figures 5-8 and 5-9 and Table 5-51 show the geographic distribution of minority and low-income population within census block groups (areas defined for monitoring census data of approximately 250 to 550 housing units) that are within 80 km (50 mi) of the Power Burst Facility. The two figures also show the location of the Power Burst Facility.

Figure 5-8 and Table 5-51 together indicate that the only significant concentrations of minority populations are generally located to the far southeast of the Power Burst Facility, at a distance beyond 48 km (30 mi) from the Power Burst Facility. Figure 5-9 shows that small numbers of low-income residents are more universally distributed in the region, with pockets containing a few low-income households in the census block group containing the Power Burst Facility and in the block group immediately to the south. The nearest population is near Howe, Idaho, about 30 km (19 mi) northwest of the Power Burst Facility, and at Atomic City, 11 km (7 mi) south southeast.

Although some low-income populations live relatively close to the northwest and southeast of the Power Burst Facility, Sections 5.7 and 5.8 indicate it is very unlikely that routine operations would affect them with radiological and non-radiological health impacts and other risks. These risks would be insignificant for any offsite population for any alternative discussed in this section. Therefore, it is unlikely that any minority or low-income population would be disproportionately affected by routine operations at Power Burst Facility.

Although unlikely, a fuel rupture accident scenario whose effects are described in Section 5.15 could result in significant air releases of radionuclides that, in turn, could affect offsite populations (up to 4 fatal cancers within 80 km [50 mi]). The windflow across the site is from the southwest. Because the minority and low-income pockets are mostly to the south and because of their distance from the facility, neither minority populations nor most low-income persons are likely to be affected. Some possibility of harm to low-income and minority populations is present when the wind is from the north or northwest, which rarely occurs (Appendix D). The maximum reasonably foreseen accident shows the emissions plume drifting straight east toward Idaho Falls, which is a high-income majority community.

No reasonably foreseen water-related radiological accident has been identified for the Power Burst Facility (Section 5.15), so it is unlikely that minority or low-income populations would be adversely and disproportionately affected through this pathway.

Radiological accidents that exceed 0.5 rem to the MEI could have some secondary effects due to environmental contamination and mitigative actions under protective action guidelines (Section 5.15). These secondary impacts could include possible loss of some agricultural crops and loss of income by minority and low-income farm workers. It is unclear whether these losses would be disproportionate.

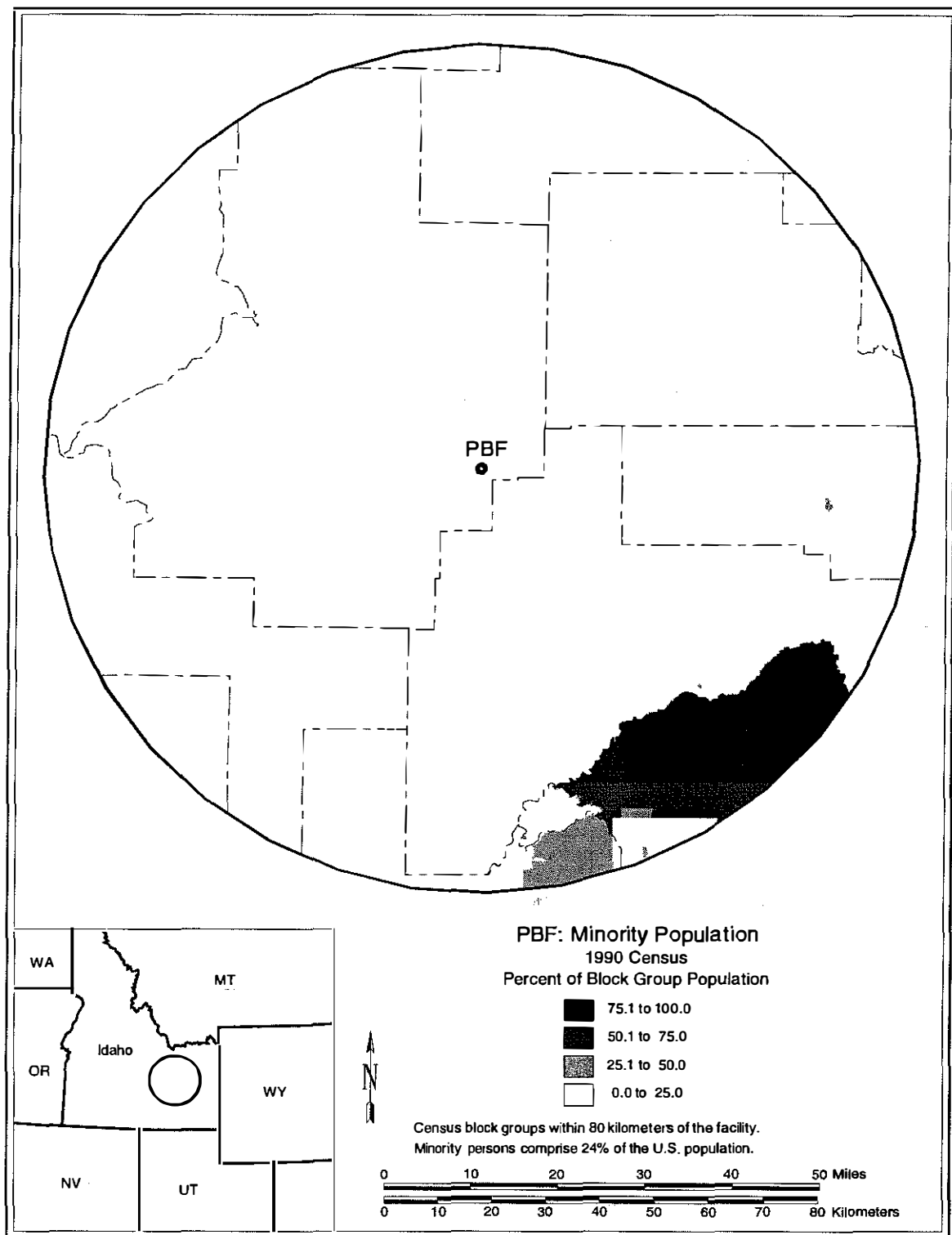


Figure 5-8. Minority Population - Power Burst Facility

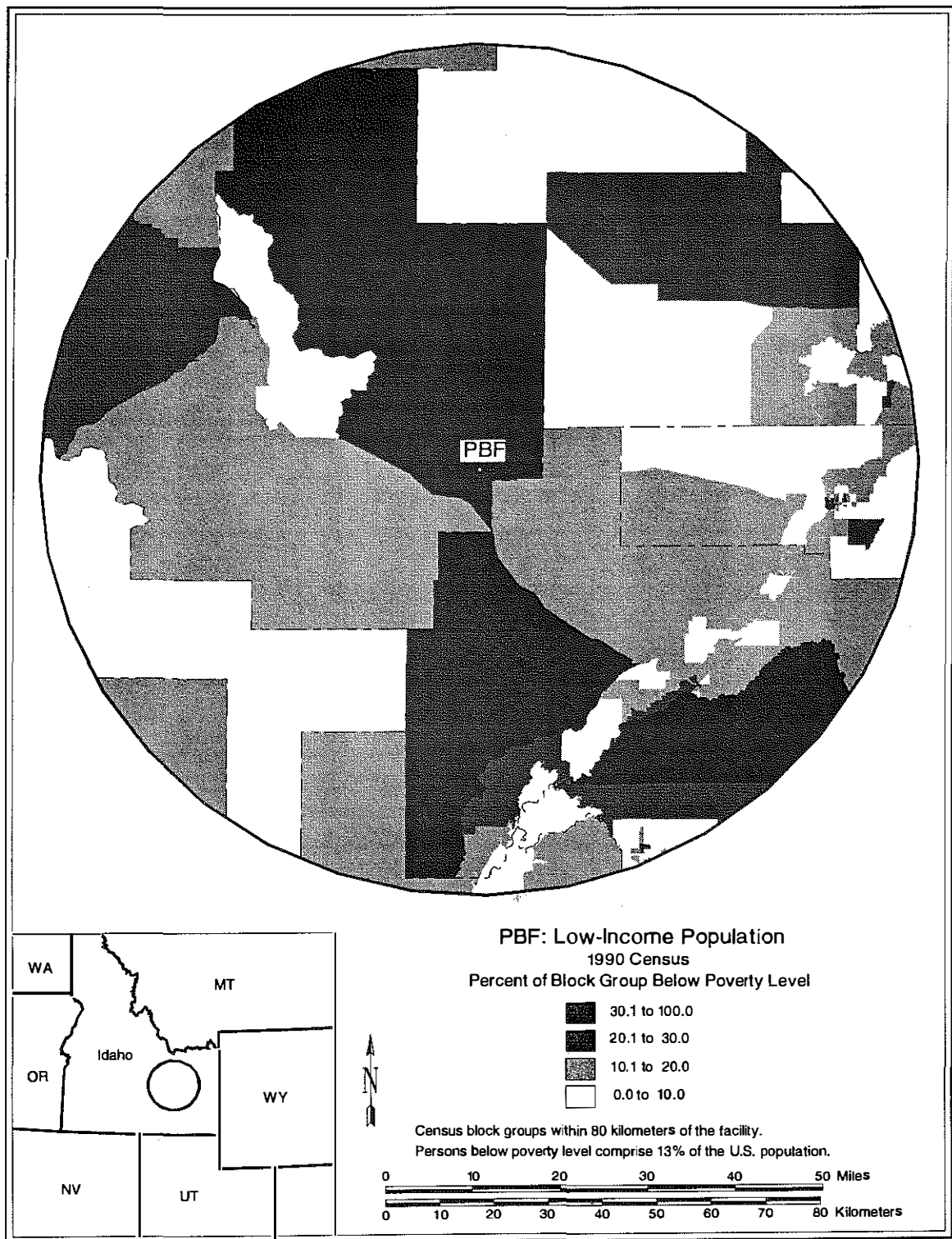


Figure 5-9. Low-Income Population - Power Burst Facility

Table 5-51. Location of Minority and Low-Income Populations Surrounding Power Burst Facility by Distance and Direction (1990 Census Data)

	Total Minority Population			Low-Income Persons		
	0-16 km (0-10 mi)	16-48 km (10-30 mi)	48-80 km (30-50 mi)	0-16 km (0-10 mi)	16-48 km (10-30 mi)	48-80 km (30-50 mi)
N	5	46	170	2	13	15
NNE	5	215	431	2	37	87
NE	7	316	752	2	40	180
ENE	19	332	7,214	3	37	1,011
E	23	739	68,380	3	92	7,246
ESE	36	607	11,469	5	82	1,330
SE	39	787	16,121	5	64	2,504
SSE	36	430	24,358	5	103	3,212
S	22	293	2,624	7	109	605
SSW	22	183	373	6	50	70
SW	15	134	293	3	21	30
WSW	13	144	233	2	24	27
W	8	180	607	2	27	68
WNW	5	586	448	2	61	78
NW	5	227	1,120	2	29	212
NNW	5	44	90	2	13	26
Total, 0-80 km (0-50 mi)			140,121			17,528

Non-radiological accidental releases would not cause impacts at the nearest point of public access (Section 5.15). No reason would exist for minorities and low-income persons to be disproportionately affected.

5.22 Costs

An important consideration when comparing alternative ways to achieve a given result is the cost of each alternative. All estimated costs included in the EIS for the proposed project were derived from cost data provided by the alternative sites. In the case of SNL/NM, they come from the Mo-99 SNL/NM Integrated Project Schedule, Pre-Baseline FY96 Schedule. For LANL, they are from the Project Planning

| Study-Los Alamos National Laboratory Mo-99 Project. For ORNL, they are from the schedule for Mo-99
| production utilizing the Oak Ridge Research Reactor, and from INEL, they are from the labor
| requirements for the Mo-99 Power Burst Facility reactor startup estimates.

| All cost analyses were performed based on the operational capabilities required by each of the
| alternative sites to produce 100% of the U.S. demand for Mo-99. Cost estimates for each alternative
| include estimated expenditures to 1) prepare the reactor facility for startup, 2) operate the reactor to
| irradiate targets, 3) prepare the hot cell facility for processing irradiated targets, 4) process the targets to
| obtain the desired product, 5) prepare the target fabrication facility for production, and 6) fabricate targets.
| Preparation costs include estimated expenditures associated with site specific process verification and
| document preparation. Operating costs include estimated expenditures associated with radioactive waste
| management processes.

| All estimated costs were based on facility preparation and operation costs specific to the production of
| Mo-99 which would be incurred at each alternative site following a Record of Decision selecting that site.
| Costs incurred at SNL/NM and LANL in FY 1995 and FY 1996 for facility cleanup of legacy materials,
| development of the Cintichem target fabrication and Mo-99 processing capabilities, and reactor and hot
| cell facility operation and management, through April 1996, were excluded from costs reported in this EIS.
| Some of these costs were incurred to develop information that would be required for and used by any site
| selected. Other costs were incurred for activities which would have been performed whether or not
| SNL/NM and LANL were selected for the proposed medical isotopes project. These adjustments resulted
| in a large reduction in estimated preparation costs for SNL/NM, compared with earlier estimates that
| included all FY 1995 and FY 1996 estimated expenditures and standby operating costs for these facilities.

The cost of providing fuel can be significant for a reactor that is operating at full power approximately
6/7 of the time. Some of the candidate reactors in this analysis have varying amounts of residual fuel
remaining from prior operations, thus reducing their startup costs and their operational costs in the early
years. Other reactors would require additional new fuel before startup. The costs for the initial new fuel
are contained in the preparation costs, with the on-going costs for replacement fuel contained in the annual
operating costs.

| Some differences among the sites' estimates can be attributed to the differences in the level of detail
| included in their cost estimates. For example, the target preparation costs at INEL and ORNL were rather
| small, about \$500 thousand, while an analysis of the LANL detailed project plan suggests a cost more like
| \$2 million. Among the estimated hot cell preparations costs provided, some differences also appeared.

| In the case of the Power Burst Facility, an additional \$450 thousand have been added to reactor
| modification costs, beyond what was reported in the Draft EIS, to account for removal of the central
| irradiation channel, manufacturing and installation of the central target grid plate, removal of transient
| rods, manufacture and installation of target holders in vacant transient rod locations, modifications of the
| central channel cooling flow path, and modification of the control system to eliminate transient operation.
| In addition, preparation of an updated Safety Analysis Report for the Power Burst Facility was the major

| component of the \$1.6 million document preparation cost estimate for INEL. Independent sources within
| DOE believe the cost to prepare and update the SAR would more likely be about \$3.0 million. Changes in
| costs figures, from those presented in the draft EIS for SNL and LANL, reflect updates in costs and
| allocations.

Nearly all of the facilities considered in these analyses have a considerable history of support to earlier DOE or U.S. Department of Defense (DOD) programs, thus the decommissioning costs should be supported in proper proportion by those earlier programs. In any event, estimates of decommissioning costs were not generally available for all candidate facilities. For this reason, decommissioning costs are not included in the comparison of candidate sites.

| The costs and numbers of full-time equivalent employees (FTEs) for the various aspects of the project,
| as derived from information provided by staff at the individual sites, are presented for comparison in Table
| 5-52. As shown in the table, the estimated preparation costs range from \$17.2 million to \$21.0 million,
| and the estimated annual operating costs range from \$8.4 million to \$12.8 million. The estimated
| SNL/NM facilities operating costs are the highest, with their estimated preparation costs second lowest.
| LANL preparation costs are also second (equivalent to those at SNL), but estimated operating costs are just
| below SNL operating costs. The estimated ORNL facilities preparation costs are the highest, with their
| estimated operating costs next to lowest. The estimated INEL facilities preparation costs are the lowest,
| with their estimated operating costs also the lowest.

| Overall, estimated expenditures for preparation and operation costs carry some level of uncertainty due
| to unknown future changes in regulation and in the rate of inflation. The level of uncertainty is somewhat
| greater in the case of estimated expenditures for ORNL and INEL, due to cost projections made at a more
| macro level than for the other two sites. It is also expected that those estimated costs would tend to
| increase if a more detailed estimating effort was performed. The SNL/NM and LANL estimates, however,
| are based on detailed analyses of the many activities that would be necessary, and those estimates should
| have smaller uncertainties.

Table 5-52. Comparison of Estimated Project Costs at Candidate Sites

	SNL/NM	LANL	ORNL	INEL
Reactor				
Prep (10 ⁶ \$)	4.4	10.3	16.4	10.3
FTEs (no.)	21.0	46.0	85.0	69.0
Opn (10 ⁶ \$/y)	6.1	6.5	5.6	5.0
FTEs (no./y)	26.0	22.0	37.0	34.0
Hot Cell				
Prep (10 ⁶ \$)	12.9	6.2	2.4	4.8
FTEs (no.)	60.0	33.0	16.0	16.0
Opn (10 ⁶ \$/y)	5.1	2.7	3.0	2.7
FTEs (no./y)	28.0	14.0	20.0	20.0
Target				
Prep (10 ⁶ \$)	1.1 LANL	1.1	0.53	0.5
FTEs (no.)	5.0	5.0	4.0	4.0
Opn (10 ⁶ \$/y)	1.6 LANL	1.6	1.0	0.7
FTEs (no./y)	8.0 LANL	8.0	5.0	5.0
Documents				
Prep (10 ⁶ \$)	1.2	2.0	1.7	1.6
FTEs (no.)	6.0	8.0	8.0	8.0
Opn (10 ⁶ \$/y)	(a)	0.2	0.06	(a)
Total Prep (10⁶\$)	19.6	19.6	21.0	17.2
Yearly Opern. (10⁶\$/y)	12.8	11.0	9.6	8.4
(a) Included in reactor and hot cell operations cost estimates.				

6.0 Regulatory Framework

The Council on Environmental Quality's National Environmental Policy Act regulations (40 CFR 1502.25[b]) require that final environmental impact statements (FEIS) list all federal permits, licenses, and other entitlements that must be obtained to implement an alternative under consideration in the FEIS. These permit and license requirements, as well as the regulatory framework affecting the various alternatives are discussed in this section.

The principal federal permit, license, or entitlement needed to implement an alternative under consideration in this FEIS is approval from the appropriate regional EPA office under the requirements at 40 CFR 61.07 and 61.08 relating to the EPA national emission standards for hazardous air pollutants. EPA approval would be needed for all but the no action alternative, because offsite projected exposure to the maximally exposed individual would exceed 1% of the EPA 0.1 mSv/yr standard for emissions of radionuclides from DOE facilities (see 40 CFR 61.96(b) and Chapter 6.16). For the SNL, Oak Ridge, and INEL alternatives, approval from EPA would be needed because projected emissions from the target processing facilities at each of these sites will exceed 1% of the 0.1 mSv/yr standard (see Tables 5-3, 5-6, and 5-8). For the alternative involving restart of the OWR reactor at LANL, EPA approval would be needed because projected emissions from the reactor will exceed 1% of the 0.1 mSv/yr standard (see Table 5-5).

Two other conditional approvals may be needed. If DOE were to choose to have a private vendor supply targets for use in a DOE reactor (See Section 3.1.2), the private vendor would need to obtain a license from the NRC or an Agreement State (See Section 6.19). In addition, each pharmaceutical manufacturer of Tc-99 generators desiring to purchase molybdenum-99 (Mo-99) from DOE may need to seek FDA approval to add DOE as a Mo-99 manufacturer; a pharmaceutical manufacturer or supplier purchasing iodine-125, iodine-131, or xenon-133 from DOE may need to obtain FDA approval to market these products (see Section 6.2).

6.1 Radiological Safety Oversight

DOE facilities for target fabrication, target irradiation, the recovery of Mo-99 and other isotopes, and for waste storage and disposal are not subject to the licensing and regulatory requirements of the U.S. Nuclear Regulatory Commission (NRC). This exemption derives from the exclusion in Section 110(a) of the Atomic Energy Act and that Section 11 of the Act excludes DOE from the definition of *person*. Contractors who operate U.S. government facilities for DOE are also exempt from NRC licensing (10 CFR 30.12, 50.11).

In lieu of NRC licensing and safety oversight, all DOE nuclear facilities are constructed and operated in compliance with applicable mandatory DOE directives.^(a) DOE directives are issued under the authority of Section 161(i)(3) of the Atomic Energy Act, which authorizes DOE to manage activities authorized by the Act.

Many DOE directives affecting radiological safety apply to operation of the facilities associated with the alternatives under consideration in this EIS. Among the more significant directives are the following:

- DOE Order 420.1, "Facility Safety"
- DOE Order 425.1, "Startup and Restart of Nuclear Reactors"
- DOE Order 460.2, "Departmental Materials Transportation and Packaging Management"
- DOE Order 5400.5, "Radiation Protection of the Public and the Environment"
- DOE Order 5480.4, "Environmental Protection, Safety, and Health Protection Standards"
- DOE Order 5480.20A, "Personnel Selection, Qualification, Training, and Staffing Requirements at DOE Reactor and Non-Reactor Nuclear Facilities"
- DOE Order 5480.22, "Technical Safety Requirements"
- DOE Order 5480.23, "Nuclear Safety Analysis Reports"
- DOE Order 5480.28, "Natural Phenomena Hazards Mitigation"
- DOE Order 5480.30, "Nuclear Reactor Safety Design Criteria"
- DOE-STD-0100T, "Licensed Reactor Nuclear Safety Criteria Applicable to DOE Reactors."

On December 9, 1991, DOE published a notice of proposed rulemaking (56 FR 64316) to add a new part (10 CFR Part 830) to its regulations establishing a body of rules for DOE contractor and subcontractor activities to ensure safe operation of DOE's nuclear facilities. The proposed rule contained nine specific sections covering 1) safety analysis reports, 2) unreviewed safety questions, 3) quality assurance requirements, 4) defect identification, 5) conduct of operations, 6) technical safety requirements, 7) training, 8) maintenance, and 9) operational occurrences, as well as general provisions for the application of these rules. A final rule on the quality assurance requirements and the general provisions for their application was published in the *Federal Register* on April 5, 1994 (59 FR 15843). The rulemaking remains open with respect to all areas other than the quality assurance requirements (60 FR 45382; August 31, 1995). As the regulations become final, the nuclear safety management requirements in 10 CFR 830 will be generally applicable to the activities being considered in this EIS.

DOE has issued a proposed rule to add a new part (10 CFR Part 834) covering radiation protection of the public and the environment (58 FR 16268; March 25, 1993). Notices reopening the comment period

(a) Mandatory DOE directives are issued in the following categories: policy statements, regulations, orders, notices, and manuals. Many final and proposed DOE directives can be accessed at the following Internet addresses: <http://www.hr.doe.gov/refshelf.html>, <gopher://nattie.eh.doe.gov:2011/1>, and <gopher://dewey.tis.inel.gov:2011/1>.

on the proposed rule until October 13, 1995 were issued on August 31, 1995 (60 FR 45381) and September 13, 1995 (60 FR 47498). When issued in final form, this rule will apply to any alternative selected for implementation.

6.2 Food and Drug Administration Approvals

The Cintichem process to manufacture Mo-99 is approved by the U.S. Food and Drug Administration (FDA). No direct approvals from the FDA to manufacture Mo-99 for commercial use at a DOE government-owned contractor-operated (GOCO) reactor will be needed. However, each pharmaceutical manufacturer of metastable technetium-99 (Tc-99m) generators desiring to purchase Mo-99 from DOE may need to seek FDA approval to add DOE as a manufacturer of the Mo-99 used in the manufacturer's Tc-99 generators.

A pharmaceutical manufacturer or supplier purchasing the isotopes iodine-125, iodine-131, and xenon-133 from DOE may need to obtain FDA approval to market these products.

6.3 Transportation Requirements

Transportation of all radioactive and other hazardous materials associated with any alternative selected for implementation will comply with applicable DOE directives and the regulations of the U.S. Department of Transportation (DOT). DOE Order 460.2 "Departmental Materials Transportation and Packaging Management" will apply to all transport of unirradiated targets, irradiated targets, spent nuclear fuel, waste products, and the transport of Mo-99 and other isotopes to carriers for distribution to pharmaceutical manufacturers.

Transportation of unirradiated targets, irradiated targets, spent nuclear fuel, waste products, and Mo-99 and other isotopes that is conducted entirely on DOE property, to which public access is controlled at all times through the use of gates and guards, is subject to DOE 460.2, but is not directly subject to the DOT regulatory requirements. DOE transport of these materials over public highways will be subject to applicable DOT regulations, as well as to DOE 460.2. The DOT has requirements for marking, labeling, placarding, providing emergency response information, and the training of hazardous material transport personnel in 49 CFR 172. Specific packaging requirements for radioactive materials are in 49 CFR 173 Subpart I. These requirements invoke the NRC packaging requirements for radioactive material at 10 CFR 71. The DOT requirements for truck transportation of radioactive and other hazardous materials are in 49 CFR 177 and 49 CFR 397. Requirements affecting the shipment of Mo-99 and other isotopes by air are in 49 CFR 175. Compliance with the 49 CFR 175 requirements will be the responsibility of the air carrier chosen to transport the Mo-99 and other isotopes.

6.4 Occupational Safety and Radiation Exposure

The occupational safety requirements of the U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) are not directly applicable to DOE's government-owned contractor-operated facilities by virtue of Section 4(b)(i) of the Occupational Safety and Health Act of 1970. However, DOE Order 440.1, "Worker Safety and Health Program," requires DOE elements to implement a written worker protection program that 1) provides a place of employment free from recognized hazards that are causing or are likely to cause death or serious physical harm to their employees; and 2) integrates all requirements contained in DOE 440.1; 29 CFR Part 1960, "Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters;" and other related site-specific worker protection activities.

DOE's radiation protection standards, limits, and program requirements for protecting occupational workers from ionizing radiation resulting from the conduct of DOE activities are in 10 CFR Part 835. All activities associated with any alternative will be conducted consistent with the Part 835 requirements. The annual total effective dose equivalent limit for general employees is 0.05 Sv (5 rem) (10 CFR 835.202[a][1]). DOE Notice 441.1, issued September 29, 1995, establishes radiological protection program requirements for DOE activities that, combined with 10 CFR 835 and its associated implementation guidance, form the basis of a comprehensive program for protection of individuals from the hazards of ionizing radiation in controlled areas. DOE Notice 441.1 requires approval by the appropriate DOE Secretarial Officer or designee before an individual receives in excess of 0.02 Sv (2 rem) in any year. DOE policy is to maintain radiation exposure in controlled areas as low as reasonably achievable through facility and equipment design and administrative controls (10 CFR 835.1001).

6.5 Radiation Exposure to Members of the Public

Activities associated with any of the alternatives under consideration in this EIS will be managed in accordance with Section II of DOE Order 5400.5, which provides that DOE activities shall be conducted so that exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause an effective dose equivalent exceeding 1 mSv/yr (100 mrem/yr). Activities will be conducted in compliance with the requirement that radiation exposure to any member of the public authorized to enter the controlled area where activities associated with implementation of any alternative are conducted will not exceed 1 mSv/yr (100 mrem/yr) total effective dose equivalent (10 CFR 835.208). Air emissions resulting from the implementation of any alternative will comply with the 0.1 mSv/yr (10 mrem/yr) standard at 40 CFR 61.92. DOE will also ensure that DOT radiation level limitations for packaging in 49 CFR 173.441 and requirements related to radioactive contamination on the external surfaces of each package offered for shipment in 49 CFR 173.443 are met.

6.6 Noise

Federal efforts to regulate noise derive largely from the Noise Control Act of 1972 (42 USC 4901-4918). Under this act, federal agencies, such as DOE, are to carry out their programs to further the purpose of the act to promote an environment for all Americans that is free from noise that jeopardizes health or welfare (42 USC 4903[a]). Beyond the general obligation in the Noise Control Act, no specific requirements in the Noise Control Act or in any regulations implemented under the act prohibit or regulate the activities that would be conducted under any of the alternatives under consideration in this EIS. The Noise Control Act also requires federal agencies to meet state and local requirements relating to the abatement of noise (42 USC 4903[b]).

OSHA has issued regulations to regulate the noise exposure of occupational workers (29 CFR 1910.95). These regulations are applicable to operations at the facilities under consideration in this EIS by virtue of DOE Order 5480.4.

6.7 Floodplains and Wetlands

DOE policy is to avoid, to the extent possible, the long- and short-term adverse impacts associated with the destruction of wetlands and the occupancy and modification of floodplains and wetlands (10 CFR 1022.3). Executive Order 11988 requires federal agencies to avoid direct or indirect support of floodplain development when a practicable alternative exists. Executive Order 11990 directs federal agencies to minimize the detrimental impact of their actions on wetland, areas and avoid new construction on wetlands unless no practicable alternative exists.

6.8 Species Protection

The Endangered Species Act of 1973 requires that federal agencies not take any action that is likely to jeopardize the continued existence of any endangered species or threatened species or result in destruction or adverse modification of critical habitat for such species (16 USC 1536[a][2]). Unless otherwise permitted by regulation, the Migratory Bird Treaty Act (16 USC 703) makes it unlawful to pursue, hunt, take, capture, or kill (or to attempt any of the preceding) any migratory bird or nest or eggs of such bird. The Bald and Golden Eagle Protection Act (16 USC 668) protects bald and golden eagles.

6.9 Native American, Archaeological, and Historic Preservation Statutes

The DOE American Indian Tribal Government Policy is set forth in DOE Order 1230.2. DOE commits in the order to consult with tribal governments to ensure that tribal rights and concerns are considered prior to DOE taking actions that may affect tribes. DOE also commits to avoid unnecessary interference with traditional tribal religious practices.

The American Indian Religious Freedom Act (42 USC 1996) establishes that it is United States policy to protect and preserve for American Indians their inherent right of freedom to believe, express, and exercise their traditional religions, including access to sites, use and possession of sacred objects, and the freedom to worship through ceremonies and traditional rites. The Native American Graves Protection and Repatriation Act provides that tribal descendants shall own Native American human remains and cultural items discovered on federal lands after November 16, 1990 (25 USC 3002). When items are discovered during an activity on federal lands, the activity is to cease and appropriate tribal governments are to be notified. Work on the activity can resume 30 days after the receipt of certification that notice has been received by the tribal governments.

The Archaeological Resources Preservation Act of 1979 prohibits the excavation of material remains of past human life that have archaeological interest, and are at least 100 years old, without a permit from the appropriate federal land manager or an exemption (16 USC 470bb, 470ee).

The National Historic Preservation Act authorizes the Secretary of the Interior to maintain a National Register of Historic Places (16 USC 470a[a][1]). Federal agencies are to take into account the effect of their actions on properties included in or eligible for inclusion in the Register and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment on such actions (16 USC 470f).

6.10 Environmental Justice

Section 2-2 of Executive Order 12898 (59 FR 7629; February 16, 1994) requires each federal agency to conduct its programs, policies, and activities affecting human health or the environment so that they do not have the effect of excluding persons (including populations) from participating in, denying persons (including populations) the benefits of, or subjecting persons (including populations) to discrimination under such programs, policies, and activities.

6.11 Recreational Fisheries

Executive Order 12962 (60 FR 30769; June 7, 1995) requires federal agencies to evaluate the effects of their actions on aquatic systems and recreational fisheries.

6.12 Chemical and Material Storage

Under any alternative, chemical and material storage will be conducted according to DOE directives. In particular, DOE Order 5480.4 ("Environmental Protection, Safety, and Health Protection Standards") requires compliance by DOE and its contractors with National Fire Protection Association Codes and Standards and the Occupational Safety and Health Standards at 29 CFR 1910 issued by OSHA.

6.13 Waste Management

Implementation of any alternative, except the no action alternative, will result in the generation of small quantities of low-level radioactive waste, incidental mixed waste (combined radioactive and hazardous waste), and spent nuclear fuel.

Solid waste, such as nonradioactive waste not classified under Subtitle C of the Resource Conservation and Recovery Act (RCRA [42 USC 6901]) as hazardous waste, will be disposed of in DOE-owned landfills or in non-DOE landfills operated according to the requirements in Subtitle D of the RCRA and applicable state and local requirements.

Low-level radioactive waste will be stabilized and temporarily stored at the DOE site of generation. It will be disposed of at a DOE disposal site operated according to the requirements in Chapter III of DOE Order 5820.2A ("Radioactive Waste Management").

Mixed waste will be temporarily stored at the DOE site of generation. It will ultimately be treated and disposed of at a DOE site according to 1) the site treatment plan for the selected site developed in response to the Federal Facility Compliance Act (42 USC 6939c[b]), and 2) DOE Order 5400.3 ("Hazardous and Radioactive Mixed Waste Program"). The availability of proposed site treatment plans for various DOE sites was announced April 5, 1995 (60 FR 17346).

Spent nuclear fuel will be temporarily stored at the DOE site of generation. Storage will be according to applicable DOE directives. Ultimate storage will be consistent with the Record of Decision on the Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programmatic EIS (60 FR 28680; June 1, 1995). Thus, aluminum clad spent nuclear fuel, such as the fuel from the Omega West Reactor and the Oak Ridge Research Reactor, will eventually be shipped to the DOE Savannah River Site. Non-aluminum clad fuel, such as the fuel from the Annular Core Research Reactor and the Power Burst Facility, will eventually be shipped to or retained at Idaho National Engineering Laboratory (INEL).

6.14 Emergency Planning and Community Right-to-Know

Executive Order 12856 (58 FR 41981; August 6, 1993) requires executive branch agencies, such as DOE, to comply with the Emergency Planning and Community Right-To-Know Act (42 USC 11001-11050). The act has notification, emergency planning, and reporting requirements for entities that use or store certain hazardous substances in amounts exceeding designated quantities. INEL, Los Alamos National Laboratory (LANL), Oak Ridge National Laboratory (ORNL), and Sandia National Laboratories/New Mexico (SNL/NM) comply with the act. Their compliance will be supplemented with any additional notification, planning, or reporting requirements that may arise as a result of implementing any alternative.

6.15 Pollution Prevention

Executive Order 12856 also requires that executive branch agencies comply with Section 6607 of the Pollution Prevention Act (42 USC 131067). DOE will comply with any source reduction and recycling reporting requirements in Section 6607 that are triggered by implementation of any alternative.

6.16 Radioactive Air Emissions

All reactor and hot cell operations considered in this EIS will have radioactive air emissions. Radioactive emissions from DOE facilities are subject to the U.S. Environmental Protection Agency (EPA) National Emission Standards for Hazardous Air Pollutants requirements at 40 CFR Part 61. In particular, Subpart A ("General Provisions,") and Subpart H ("National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities") are applicable to all alternatives, except the no action alternative.

Subpart H provides that emissions of radionuclides to the ambient air from a DOE facility are not to exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 0.1 mSv/yr (10 mrem/yr) (40 CFR 61.92). For all new construction or modifications to existing facilities where the estimated effective dose equivalent will exceed 1% of the 0.1 mSv/yr standard, an application for approval of construction or modification must be submitted to the appropriate regional EPA office under the procedures at 40 CFR 61.07 (40 CFR 61.96[b]). DOE will follow the procedures in 40 CFR 61 Subparts A and H for any alternative selected for implementation.

Both radioactive and nonradioactive air emissions from any alternative selected for implementation will eventually be covered in the sitewide operating permit for the selected DOE site(s). Operating permits are issued by state permitting authorities whose operating permit program has been approved by the EPA under the program requirements at 40 CFR Part 70 or by the EPA under regulations to be codified at 40 CFR Part 71 for states without an approved operating permit program.

6.17 Nonradioactive Air Emissions

Nonradioactive air emissions from any alternative selected for implementation will be emitted in very small quantities and are not expected by themselves to trigger any air permit requirements, including requirements relating to prevention of significant deterioration permits in attainment areas (40 CFR 52.21) and nonattainment permits in nonattainment areas (40 CFR 51.165).

The EPA's general conformity rule requires that federal agencies prepare a written conformity analysis and determination covering compliance with an applicable state implementation plan for proposed activities where the total of direct and indirect emissions of a nonattainment or maintenance criteria pollutant caused by the activity will exceed the threshold emission levels shown at 40 CFR 93.153(b). Of the sites under consideration in this EIS, the only site that is located in an area that has nonattainment status for a criteria pollutant is SNL/NM, which is in an area that is nonattainment for carbon monoxide. The threshold emission level for carbon monoxide is 100 tons/yr. Carbon monoxide emissions from the SNL/NM Mo-99 production alternative would be below this level. Consequently, a conformity analysis and determination is not required.

6.18 Liquid Discharges to the Ground or Publicly Owned Treatment Works

Liquid wastes will normally be solidified and treated and disposed of consistently with the waste management procedures identified in Section 6.13. When possible, wastewater will be decontaminated and reused. Wastewater that is not solidified or reused will be treated to remove radionuclides. For all but the no action alternative, some wastewater containing small residual quantities of radionuclides after treatment will require periodic disposal to the ground, a publicly owned treatment works, or both. Any discharge of contaminated wastewater to the ground will comply with any applicable state or local permit requirements and applicable DOE directives including DOE Order 5400.5 ("Radiation Protection of the Public and the Environment") and DOE Order 5480.4 ("Environmental Protection, Safety, and Health Protection Standards.") Any discharge of contaminated wastewater to a publicly owned treatment works will comply with applicable DOE directives and the EPA regulations at 40 CFR 403 concerning pretreatment requirements for discharges to such treatment works.

6.19 Special Requirements for Targets Supplied to DOE by a Private Vendor

The DOE is considering contracting with a private vendor to supply targets for use in a DOE reactor. Permit and license requirements applicable to such a private vendor would differ somewhat from those affecting target fabrication at a DOE facility.

A private vendor supplying targets to DOE would need to be licensed by the NRC (10 CFR 70.3) or an Agreement State, if the target fabrication facility is located in an Agreement State and the quantity of highly enriched uranium used in the target manufacturing process is insufficient to form a critical mass (10 CFR 150.10, 150.11). Conditions for approval of a license application are listed at 10 CFR 70.23. Radiation exposure to occupational workers and the public as a result of target fabrication activities would need to be in compliance with the NRC requirements at 10 CFR 20 or comparable Agreement State requirements. All transportation of targets to the DOE irradiation facility would need to be in compliance with the NRC packaging requirements at 10 CFR 71 and all applicable DOT requirements. Low-level radioactive waste generated by the private vendor would be shipped to a commercial low-level waste disposal site licensed by the NRC under the requirements at 10 CFR 61 or by an Agreement State.

6.20 Environmental Review and Consultation

Preparation of the MIPP-EIS was coordinated with other governmental agencies to integrate the NEPA process and to comply with other environmental review requirements in accordance with DOE's NEPA regulations, the Council on Environmental Quality regulations, and other statutes, such as the *Fish and Wildlife Coordination Act* (16 USC 661 et seq.), the *National Historic Preservation Act* of 1966 (16 USC 470 et seq.), and the *Endangered Species Act* of 1973 (16 USC 1531 et seq.).

Copies of the Draft EIS were sent to appropriate Native American tribes, and Federal, state, county, and city agencies, as well as advisory groups. Copies were also sent to all other agencies and persons who have requested them. Recipients of copies of the Draft EIS included, but were not necessarily limited to, the following organizations or groups:

Native American Groups

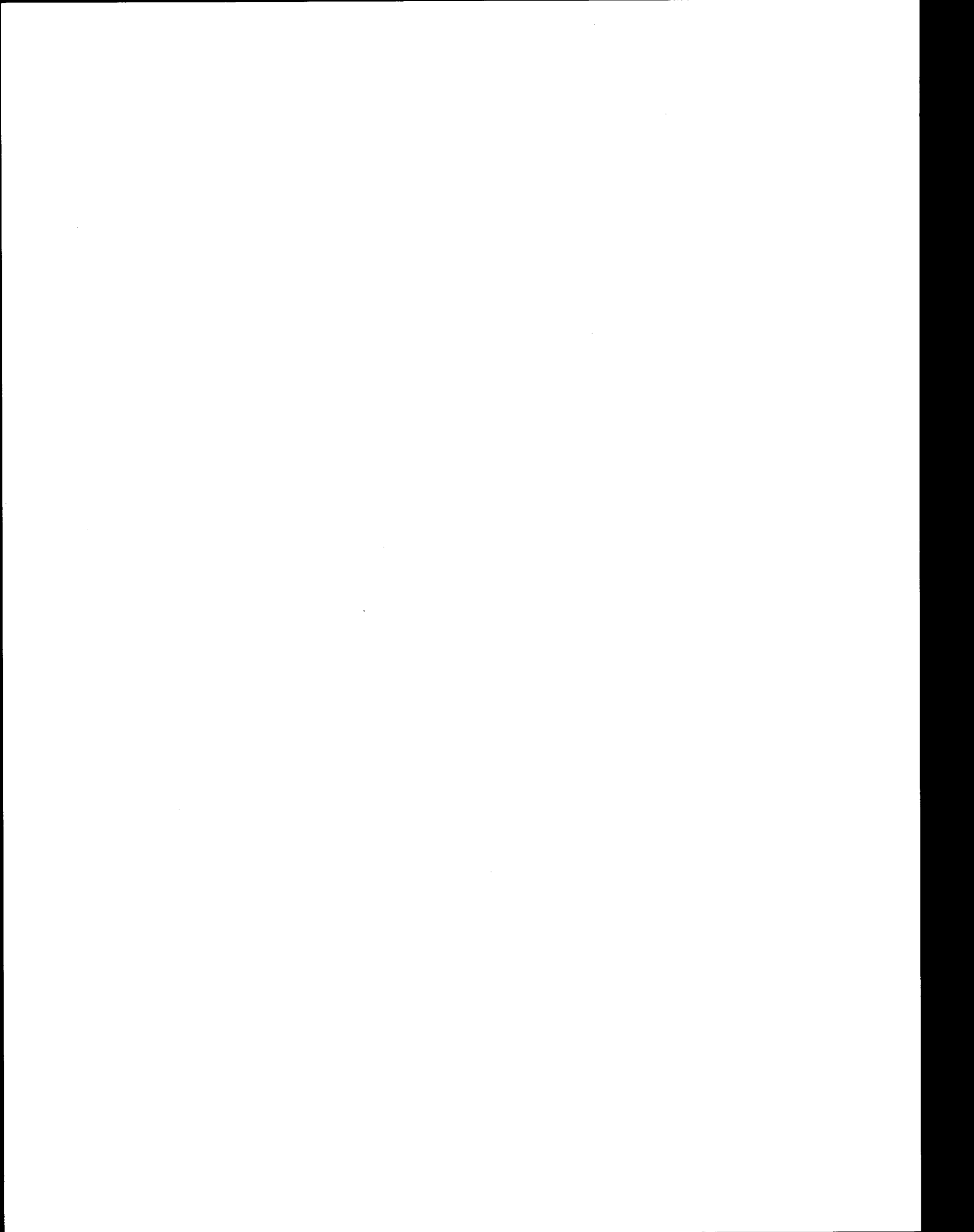
- Cochiti Pueblo
- Isleta Pueblo
- Jemez Pueblo
- Nambe Pueblo
- Picuris Pueblo
- San Felipe Pueblo
- San Ildefonso Pueblo
- San Juan Pueblo
- Sandia Pueblo
- Santa Clara Pueblo
- Santo Domingo Pueblo
- Taos Pueblo
- Tesuque Pueblo

Federal Agencies

- U.S. Air Force, Kirtland Air Force Base
- U.S. Department of the Interior, U.S. Fish and Wildlife Service
 - Boise Field Office
 - Cookeville Field Office
 - New Mexico Ecological Services State Office
- U.S. Environmental Protection Agency
- U.S. Food and Drug Administration

State Agencies

- Idaho Department of Fish and Game
- State of New Mexico Department of Public Safety
- State of New Mexico Environment Department
- State of New Mexico Energy, Minerals and Natural Resources Department
- State of New Mexico Department of Fish and Game
- State of Tennessee Department of Environment and Conservation
- State of Tennessee Department of Economic and Community Development
- State of Idaho Department of Health and Welfare
- Tennessee Wildlife Resources Agency



7.0 Glossary of Terms

In this section, glossary terms are defined in the context used in this FEIS.

6-day curie. The conventional unit defined as the amount of radioactivity that will result in 1 curie remaining after a 6-day period of decay.

accelerator. A device for imparting kinetic energy to charged particles, such as electrons, protons, deuterons, and helium ions. Common types of accelerators are the cyclotron, synchrotron, synchrocyclotron, betatron, linear accelerator, and Van de Graff electrostatic generator.

activity (radioactivity). Activity is a measure of the quantity of a radioactive substance. The SI unit of measure is the becquerel (Bq), which is equal to one disintegration (nuclear transformation) per second. The common unit of activity is the curie (Ci) which is equal to 37 billion disintegrations per second - this number of disintegrations is approximately the disintegration rate of one gram (0.04 oz) of radium from which the original definition came. One Ci equals 3.7×10^{10} Bq and is the unit of activity used in this Environmental Impact Statement (EIS).

aerosolize. The process of converting a solid or a liquid into a gaseous suspension of fine particles (an aerosol).

air lock. An intermediate chamber between the outer air and a working chamber, generally for the purpose of accommodating transfer of materials while maintaining chamber isolation.

air quality. The quality of air as determined by comparison of the quantity of pollutants in the air with applicable standards.

air quality standards. The prescribed quantity of pollutants in the outside air that cannot be exceeded legally during a specified time in a specified area.

alluvium. Clay, silt, sand, gravel, or similar material deposited by running water.

ambient air. The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not the air in immediate proximity to emission sources.

aqueous. Relating to or resembling water.

aquifer. A water-bearing stratum of permeable rock, sand, or gravel.

aquitard. A bed of low permeability adjacent to an aquifer; may serve as a storage unit for ground water, although it does not yield water readily.

as low as reasonably achievable (ALARA). An approach to radiological control to manage doses (individual and collective) received by the work force and to the general public at levels as low as is reasonable, taking into account social, technical, economic, practical, and public considerations. As normally used in this document, ALARA is not a dose limit, but a process with the objective of attaining doses as far below the applicable controlling limits as is reasonably achievable, taking into account social and economic considerations.

attainment area. An area considered to have air quality as good as, or better than, the national ambient air quality standards, as defined in the Federal Clean Air Act. An area may be an attainment area for one pollutant and a non-attainment area for others.

background radiation. Radiation resulting from cosmic rays entering from space and from naturally occurring radionuclides of cosmic or primordial origin. Background radiation varies with location, depending on altitude and natural radioactivity present in the surrounding geology. Background radiation sometimes includes that from worldwide fallout from weapons testing (about 4 mrem/yr), but is not included in this FEIS.

beryllium (Be). A rare metal (average atomic mass of about 9 atomic mass units) used most commonly in the manufacture of beryllium-copper alloys for numerous industrial and scientific applications. It is on the EPA's list of priority metals for hazardous air pollutants.

bound, bounding. A description of the evaluation process that provides a reasonable upper limit to potential consequences or impacts.

breccia. A coarse-grained rock composed of angular broken rock fragments held together by a naturally occurring mineral cement.

°C. Degree Celsius. $^{\circ}\text{C} = 5/9 \times (^{\circ}\text{F} - 32)$.

cancer. Any malignant new growth of abnormal cells or tissue.

charcoal filter. Used to trap fission product gases from nuclear reactors and radiochemical operations. These filters, also known as activated-carbon absorbers, are made of tightly packed beds of absorbent carbon granules.

Ci. *See curie.*

collective dose. The sum of the individual doses to all members of a specific population.

concentration. The amount of a substance contained in a unit quantity (mass or volume) of a sample.

conglomerate. A coarse-grained sedimentary rock composed of rounded fragments larger than 2 mm (0.08 in.) in diameter set in fine-grained sand or silt. It is commonly cemented naturally by a mineral cement.

control rod. Any rod used to control the reaction rate in a nuclear reactor, typically by absorption or reflection of neutrons.

core. In a nuclear reactor, the region containing the fissionable material. The body of fuel or moderator and fuel in a nuclear reactor.

criteria pollutants. Six pollutants (ozone, carbon monoxide, total suspended particulates, sulfur dioxide, lead, and nitrogen oxide) known to be hazardous to human health and for which the EPA sets National Ambient Air Quality Standards under the Clean Air Act.

criticality. A state in which a self-sustaining nuclear chain reaction is achieved.

cumulative impacts (effects). The sum of environmental impacts, by category, for past, proposed, and reasonably foreseeable future actions.

curie (Ci). A unit of radioactivity equal to 37,000,000,000 (3.7×10^{10}) disintegrations per second.

dBA. Decibel on the A-weighted scale (*see decibel and decibel, A-weighted*).

decibel. An expression of sound pressure level that is referenced to a pressure of 10 micropascals expressed on a logarithmic scale, $1 \text{ dB} = 20 \log_{10} (p/20)$, where p is the sound pressure in micropascals. Twenty micropascals approximates the minimum audible sound pressure level in humans (*see also decibel, A-weighted*).

decibel, A-weighted. The A-weighted decibel (dBA) is an expression of adjusted pressure levels by frequency that accounts for human perception of loudness. Consequently, dBA is most often used when evaluating human noise disturbance. For example, at a frequency of 500 Hz, 60 dB are reduced by 3.2 dB to give an A-weighted pressure level of 56.8 dBA. Lower frequencies are reduced more because they are less of an annoyance to humans, and higher frequencies are reduced less because they are more of an annoyance (*see also decibel*).

decay, radioactive. The spontaneous transformation of an unstable atom to a lower, more stable energy state, often with the emission of particulate or electromagnetic radiation (alpha, beta, gamma, or x-radiation).

decommission. To formally remove a facility, or facilities, from service.

decontamination. Process of removing radioactive contamination and materials from personnel, equipment, or areas.

depleted uranium. A mixture of uranium isotopes where uranium-235 represents less than 0.7% of the uranium by mass.

dose (radiation dose). In terms of public health and safety, radiation dose is a measure of the amount of ionizing radiation absorbed by the body or body tissue. The unit of absorbed dose in SI units is the gray (Gy) and is equal to the deposition of one joule of energy per kilogram of tissue and in common units is the rad, which is equal to the deposition of 100 ergs per gram of tissue.

Various forms of radiation have different impacts on tissues and different tissues have different responses in terms of overall impact on the body. The source of radiation may originate outside the body, or inside the body as a result of inhalation, ingestion, adsorption, or injection. Adsorbed dose by itself is generally not sufficient as a measure of detriment or impact. As a consequence, a total effective dose equivalent (TEDE) has been defined to take into account these differences and which yields a single risk-based value. Typically, TEDE, as used in this FEIS, includes the 50-yr committed dose from radionuclides internal to the body and the radiation dose received from external sources from one year's exposure (multiple exposures and cumulative dose are taken into account as appropriate). The special name of the unit of total effective dose equivalent is the sievert (Sv) in SI units and the rem in common units. One Sv equals 100 rem. (The fundamental units of effective dose equivalent are such that one sievert is equal to one joule of energy per kilogram of absorbing medium).

Typically, the TEDE (usually referred to simply as dose in this FEIS) is calculated for a maximally exposed individual (MEI) and for populations of interest. The MEI is that hypothetical individual who, by virtue of food consumption patterns, place of residence, *et cetera*, tends to receive the maximum dose for a given release of radionuclides to air, water, or ground. In this FEIS, the MEI dose is reported in rem or mrem (one-one thousandth of a rem). Population doses are based on doses to individuals using more typical assumptions for exposure and intake. The doses for individual members of the population are added together to obtain the collective dose to the population. In this EIS, population dose is reported in person-rem.

dose equivalent. Some types of radiation, such as neutron and alpha, deposit their energy more densely in affected tissue than gamma radiation and, thereby, cause more damage to tissue. This term, measured in units of rem, is used to take into account this difference in tissue damage. The units of dose equivalent are the rem and sievert (Sv) (*see dose*).

dose rate. The radiation dose delivered per unit time (for example, rad/h).

dosimeter. Instrument used to detect and measure an accumulated dosage of radiation.

ecology. The science dealing with the relationship of all living things with each other and with the environment.

ecosystem. A complex of the community of living things and the environment forming a functioning whole in nature.

effective dose equivalent. A concept used to estimate the biological effect of ionizing radiation. It is the sum over all body tissues of the product of absorbed dose, the quality factor (to account for the different penetrating abilities of the various types of radiation), and the tissue weighing factor (to account for the different radiosensitivity of the various tissues of the body) (*see dose*).

effluent. Typically, liquid released from process control.

EIS. Environmental impact statement; a document required by Council on Environmental Quality regulations for implementing the procedural provisions of the National Environmental Policy Act (NEPA) of 1969, as amended, for proposed major federal actions involving potentially significant environmental impacts.

element. One of the known chemical substances that cannot be divided into simpler substances by chemical means. All isotopes of an element have the same atomic number (number of protons) but have a different number of neutrons, and thus different atomic weights.

emission standards. Legally enforceable limits on the kinds and quantities of air contaminants that can be emitted into the atmosphere.

endangered species. Any species that is in danger of extinction throughout all or a significant portion of its range, other than the Class Insecta determined by the Secretary to constitute a pest whose protection under the provisions of the Endangered Species Act would present an overwhelming and overriding risk to man..

enriched uranium. Uranium in which the abundance of the U-235 isotope is increased above the naturally occurring amount of 0.71%.

environment. The sum of all external conditions and influences affecting the life, development, and ultimately the survival of an organism or ecological community.

environmental monitoring. The act of measuring, either continuously or periodically, some quantity of interest, such as radioactive material in the air.

ephemeral stream. A stream carrying water only during and immediately after periods of rainfall or snowmelt.

epicenter. The point on the earth's surface directly above the focus of an earthquake.

erosion. A general term for the natural processes by which earth materials are loosened, dissolved, or worn away and moved from one place to another. Typical processes are wind and water as they carry away soil.

| **eutectic.** An alloy or solution that has the lowest possible constant melting point.

extraction. First step performed in the chemical separation of the molybdenum-99 from the other fission products that are produced during the irradiation of uranium-235. Additional chemical separations are then performed to purify the molybdenum-99 product.

°F. Degree Fahrenheit. $^{\circ}\text{F} = (^{\circ}\text{C} \times 9/5) + 32$.

fault. A fracture or a zone of fractures within a rock formation along which vertical, horizontal, or transverse slippage of the earth's crust has occurred in the past.

fission. Splitting of a heavy nucleus into two approximately equal parts (rarely three unequal parts), which are nuclei of lighter elements accompanied by the release of energy and generally one or more neutrons. Fission can occur spontaneously or can be induced by nuclear bombardment.

fissionable. Atoms capable of being split or divided (fissioned) by the absorption of thermal neutrons. The most common fissionable materials are uranium-233, uranium-235, and plutonium-239.

fission products. Nuclides resulting from the fission process.

forb. A general term for a weed or broad leaf flowering plant as distinguished from grasses and sedges.

formation. A body of rock identified by lithic characteristics and stratigraphic position. Formations may be combined into groups or subdivided into members.

| **fuel meat.** The portion of the fuel that will fission.

gamma radiation. Short wavelength electromagnetic radiation (photons of nuclear origin with a range of wave lengths from about 10^{-8} to 10^{-11} cm (0.01 to 10 MeV), emitted from the nucleus of an atom.

GENII. A computer program used to estimate doses to individuals and populations from releases of radioactive materials.

geology. The science that deals with the earth; the materials, processes, environments, and history of the planet, especially the lithosphere, including the rocks, their formation, and structure.

glove box. A sealed box with gloves attached and passing through openings into the box, so that workers can handle materials inside without inhalation of contaminants.

gram (g). One 1-thousandth of a kilogram, nearly equal to the mass of one cubic centimeter of water.

ground water. All subsurface water, especially the part that is in the zone of saturation.

habitat. The part of the physical environment in which a plant or animal lives.

half-life (radiological). The time in which half the atoms of a radioactive substance disintegrate to another nuclear form. Half-lives vary from small fractions of a second to billions of years.

halogen. Elements of chemical group VII (that is, having a valence shell that lacks one electron). These chemically reactive elements include fluorine, chlorine, bromine, iodine, and astatine.

hazardous waste. Waste that contains hazardous constituents but no radionuclides. Hazardous waste is generated at most U.S. Department of Energy installations in a variety of quantities and forms. For the most part, hazardous waste is sent to commercial treatment and disposal facilities.

high efficiency particulate air (HEPA) filter. Disposable, extended pleated-medium dry-type filter with: 1) a rigid casing enclosing the full depth of the pleats, 2) a minimum particle removal efficiency of 99.97% for thermally generated monodisperse dioctyl phthalate (DOP) smoke particles with a diameter of 0.3 micrometer, as measured in the laboratory, and 3) a maximum pressure drop of 1-in. water gauge when clean and operated at its rated airflow capacity.

high-level waste. The highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly from reprocessing and any solid waste derived from the liquid that contains a combination of transuranic and fission product nuclides in quantities that require permanent isolation. High-level waste may include other highly radioactive material that the U.S. Nuclear Regulatory Commission, consistent with existing law, determines by rule requires permanent isolation.

hot cell. A heavily shielded room in which highly radioactive materials can be handled, generally by remote control.

intensity (earthquake). A numerical rating used to describe the effects of earthquake ground motion on people, structures, and the earth's surface. The numerical rating is based on an earthquake intensity scale such as the modified Mercalli Scale commonly used in the United States.

interbed. A typically thin bed of one kind of rock material occurring between or alternating with beds of another material.

ion. An atom or molecule that has gained or lost one or more electrons to become electrically charged.

ionizing radiation. Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, during its passage through matter.

irradiation. Exposure to radiation; typically exposure to neutron radiation that might be present near or within the core of a nuclear reactor.

isomer. An isomer is simply an isotope with additional energy in the nucleus. Most isomers decay and keep the same number of protons and neutrons in the nucleus, thereby retaining their isotopic status, but with less energy in the nucleus. Some isomers undergo beta decay, thereby changing both their isotopic and elemental status.

isotope. One of several nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but differing in the number of neutrons, and therefore in the mass number (such as, uranium-235, uranium-238, thus isotopes of uranium).

lacustrine. Belonging to or produced by lakes.

laser. A device for generating coherent electromagnetic radiation in the ultraviolet, visible, or infrared regions of the spectrum.

latent cancer fatalities. Deaths ultimately caused by a radiation-induced cancer. The cancer becomes evident years after the radiation exposure. Latent cancer fatalities can be calculated for the public by using the risk conversion factor of 5×10^{-4} deaths per person-rem. In the tables in this document, latent cancer fatalities less than one in a population are shown as "none" followed by the actual calculated value (in parentheses).

light water . ordinary water.

linear accelerator . A device in which atomic particles travel in a straight line as their velocity is increased. A particle accelerator that accelerates electrons, protons, or heavy ions in a straight line by the action of alternating voltages.

liter. A unit of volume equivalent to 1.057 U.S. quarts.

low-income community. A community where 25% or more of the population is identified as living in poverty.

low-level mixed waste. Waste that includes low-level waste that also is contaminated with hazardous constituents regulated under Subtitle C of the RCRA. Until the late 1980s most low-level mixed waste was routinely disposed of by shallow land burial. Low-level mixed waste is currently not disposed of by the U.S. Department of Energy. It can however, be stored for 1 year in facilities that meet specified requirements.

low-level waste. All radioactive waste not classified as high-level waste, mixed waste, and transuranic waste. Low-level waste ranges from low-activity waste that can be disposed of by shallow land disposal techniques to high-activity waste that requires disposal techniques providing greater confinement. Low-level waste is disposed of at Savannah River Site, Oak Ridge Reservation, Idaho National Engineering Laboratory, the Nevada Test Site, Los Alamos National Laboratory, and Hanford.

maximally exposed individual (MEI). A hypothetical individual who, by virtue of location and lifestyle, receives the maximum exposure to effluent from a facility.

medical isotope. A radioactive isotope that is used for the purpose of medical treatment or diagnosis. Some medical isotopes are technetium-99m, iodine-125, iodine-131, xenon-133, and cobalt-60. These isotopes can be prepared into a variety of chemical forms, depending on the specific medical need.

metastable. Changing readily either to a more stable or less stable condition.

migration. The movement of a material through the soil or ground water.

mixed waste. Waste that contains a radioactive component regulated under the Atomic Energy Act and a hazardous component regulated by the EPA under the RCRA.

National Register of Historic Places. A list maintained by the National Park Service of architectural, historic, archeological, and cultural sites of local, state, or national importance.

natural background radiation. Radiation originating from naturally occurring sources. Principal sources of background radiation are primordial radionuclides such as uranium, thorium, and potassium-40 and cosmic radiation. Radiation may be produced or enhanced by man-made means, such as activation or nuclear fission.

NEPA. National Environmental Policy Act of 1969 as amended.

neutralize. To make chemically neutral, or to adjust the pH to approximately 7.

noble gas. Elements of chemical group VIII (those having a complete valence shell). These chemically inert elements include isotopes of helium, neon, argon, krypton, xenon, and radon, which typically exist as gases at normal pressures and temperatures.

nonhazardous waste/industrial and sanitary waste solid. Solid sanitary waste (for instance, garbage, rubble, or debris) regulated under Subtitle D of the RCRA and liquid sanitary waste regulated under the Clean Water Act. Sanitary waste is generated at all U.S. Department of Energy sites and is disposed of onsite and offsite at departmental, public, or private facilities.

North American demand. Term used to define the total demand for medical radioisotopes for the North American Continent (including the United States, Canada, and Mexico). This term defines the production requirement (approximately 16,400 curies from the reactor) to satisfy 100% of the North American Mo-99 annual demand.

NO_x. Oxides of nitrogen, primarily nitrogen oxide (NO) and nitrogen dioxide (NO₂). These oxides are produced in the combustion of fossil fuels, and can constitute an air pollution problem.

nuclear weapon. The general name given to any weapon in which an explosion can result from the energy released by reactions involving atomic nuclei, either fission, fusion, or both.

nuclear stockpile. The total aggregation of the nation's nuclear weapons that are in the custody of the U.S. Department of Defense. This quantity is defined in the nuclear weapons stockpile memorandum.

nuclear reaction. An interaction between a photon, particle, or nucleus and a target nucleus, leading to the emission of one or more particles and photons.

nuclide. A species of atom, characterized by its nuclear constitution (number of protons and number of neutrons).

numerical notation. Various means of expressing numerical values, particularly very large or very small values. Examples of types of numerical notation include scientific, exponential, or floating point. (*see Units of Measure preceding Section 1.0*)

outfall. Place where liquid effluent enter the environment and are monitored.

oxide. A compound in which an element has chemically combined with oxygen.

ozone. A molecule of oxygen in which three oxygen atoms are chemically attached to each other.

particulates. Solid particles and liquid droplets small enough to become airborne.

perched water. A body of ground water separated from an underlying body of ground water by an unsaturated zone.

perennial stream. A stream that contains water at all times except during extreme drought.

permeability. Ability of liquid to flow through rock, ground water, soil, or other substance.

person-rem. Unit of collective dose, collective committed effective dose equivalent, etc.

pH. A measure of the hydrogen ion concentration in aqueous solution. Pure water has a pH of 7, acidic solutions have a pH less than 7, and basic solutions have a pH greater than 7.

physiographic. Pertaining to the physical features of the earth's surface, such as land forms or bodies of water.

PM₁₀. Particulate matter with a 10-micron, or less, aerodynamic diameter.

pollution. The addition of an undesirable agent to the environment in excess of the rate at which natural processes can degrade, assimilate, or disperse it.

probability. The chance that a given event will occur.

Puye Formation. A stratigraphic unit composed of basalts, interflow breccias, conglomerates, sandstones, and siltstones that underlies Los Alamos National Laboratory.

rabbit. A mechanical device allowing access to a reactor without shutting it down.

radiation. The emitted particles or photons from radioactive atoms. Emission and propagation of energy through space or through a material in the form of waves; for instance the emission and propagation of electromagnetic waves.

radiation dose. (*see dose*)

radioactive waste. Materials from nuclear operations that are radioactive or are contaminated with radioactive materials and for which there is no practical use or for which recovery is impractical (*see low-level waste*).

radioactive air emissions. Air effluent that contains a radioactive component.

radioactivity. The property possessed by some elements (such as uranium) of spontaneously emitting alpha or beta particles, and sometimes gamma rays by disintegration of the nucleus of the atoms.

radiography. The technique of producing a photographic image of an opaque specimen by transmitting a beam of x-rays or gamma rays through it onto an adjacent photographic film; the image results from variations in thickness, density, and chemical composition of the specimen.

radioisotope. A radioactive isotope.

radiological impact. Refers to impacts on human health due to external exposure, or intake of radioactive materials into the body. These impacts are typically described in terms of dose, damage to body organs, or the induction of cancer.

radionuclide. A nuclide that is radioactive.

radiopharmaceuticals. Term used to describe products that include radioactive materials (medical isotopes) and are prepared, produced, or packaged by the pharmaceutical industry for use in nuclear medicine.

reactor. A system in which nuclear fission may be sustained in a self-supporting chain reaction. It includes fissionable material, such as uranium, and moderating material, such as graphite or water, provision for heat removal, and control elements.

recharge. The processes involved in adding water (that is, rainwater) to an aquifer.

rem. The common unit of dose equivalent, effective dose equivalent, for a single individual, used in the field of radiation dosimetry.

RIMS. Regional Input-Output Modeling System. A software package produced by the U.S. Department of Commerce to evaluate community impacts of economic activities.

risk. The term risk has many interpretations; however, for present purposes, risk means the product of the probability of an event occurring, or the estimated frequency of an event, over the period of interest and the consequences of the event, if it were to occur.

runoff. The portion of rainfall, melted snow, or irrigation water that flows across the ground surface and eventually returns to streams.

seismicity. The relative frequency and distribution of earthquakes.

shield, shielding. Material used to absorb radiation, thereby reducing its intensity."

Sievert (Sv). A unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv = 100 rem).

spent nuclear fuel. Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing, and is typically stored in water pools. Most spent fuel is stored in water pools, which requires constant maintenance. Spent fuel requires permanent isolation in a geologic repository.

stabilization. The action of making a material more stable by converting its physical or chemical form or placing it in a more stable environment (such as, converting metallic uranium to uranium dioxide).

steel confinement box. For the purpose of Mo-99 production, a steel confinement box is a box consisting of shielding used to protect personnel outside the box from exposure to radiation, manipulators for working inside the box remotely (without handling the materials directly), and a ventilation system that filters all air exhausted from the box.

strata. Layers of rock usually in a sequence.

stringer. An irradiation container for targets.

target. Cylindrical sealed elements irradiated in a reactor core for the purpose of generating radionuclides, either from fission or by absorption of neutrons (neutron activation). Fission targets contain enriched uranium plated on the inner cylinder wall for the purpose of generating numerous radionuclides from fission of uranium-235. Absorption (activation) targets contain isotopes by which neutron absorption produces the desired radionuclide.

threatened species. Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

TEDE. Total Effective Dose Equivalent. (*see dose*).

toxicological impact. Impact on human health, due to exposure to, or intake of, chemical materials. These impacts are typically described in terms of the damage to organs or the induction of cancer.

transuranic waste. Material contaminated by emitting transuranic nuclides (atomic number greater than 92) with half-lives greater than 20 years and in concentrations greater than 100 nanocuries per gram of material.

tritium. A radioactive isotope of hydrogen; its nucleus contains one proton and two neutrons.

tuff. A type of rock formed of compacted volcanic fragments.

units of measure. The principal units of measurement used in the FEIS are SI units, a metric system, accepted by the International Organization for Standardization as the legal standard at a meeting in

Elsinore, Denmark in 1966. SI is the abbreviation for Systeme International d' Unites. In that system, almost all units are made up of combinations of six basic units, of which length in meters, mass in kilograms, and time in seconds are of importance in this FEIS.

In this FEIS, values given in SI units are followed by values given in common units in parentheses.

uranium (U). A heavy (average atomic mass of about 238 atomic mass units), silvery-white metal with 14 radioactive isotopes.

x-ray. A penetrating electromagnetic radiation, which may be generated by accelerating electrons to high velocity and suddenly stopping them by collision with a target material, or by transition of atoms to lower energy states.

8.0 List of Preparers and Contributors

This list identifies individuals who were principal preparers of and contributors to this Final Environmental Impact Statement (FEIS). Many other individuals contributed to FEIS preparation and review. Wade Carroll, Deputy Associate Director, Office of Isotope Production and Distribution, DOE Office of Nuclear Energy, Science and Technology, directed its preparation. Michael D. McKinney, of DOE's Pacific Northwest National Laboratory (managed by Battelle), provided overall project management and document preparation support. Emmett B. Moore was responsible for technical support to Pacific Northwest National Laboratory staff working on the FEIS. Glen T. Hanson of Battelle's Albuquerque Office provided technical review.

Name: JOHN C. ABBOTT

Affiliation: Pacific Northwest National Laboratory

Education:

- M.S., Conservation of Natural Resources, University of San Antonio, 1977
- B.A., Geography, Southwest Texas State University, 1975

Technical Experience: NEPA document preparation, ecological risk assessments, and assistance to the Council for Economic Equality (19 years)

EIS Responsibility: Section 4, Affected Environment

Name: CYNTHIA W. ABRAMS

Affiliation: Pacific Northwest National Laboratory

Education:

- B.A., Environmental Studies and Biology, University of California, Santa Cruz, 1980

Technical Experience: Ecological systems management, ecological risk assessment, CERCLA policy analysis, public involvement, and NEPA EIS authorship (10 years)

EIS Responsibility: Volume II Coordination Lead; Sections 4 and 5, Waste Management

Name: ERNEST ANTONIO

Affiliation: Pacific Northwest National Laboratory

Education:

- M.S., Colorado State University, 1992
- B.S., New Mexico Highlands University, 1988

Technical Experience: Environmental monitoring, environmental health physics, and dose calculations (4 years)

EIS Responsibility: Section 4, Affected Environment; Sections 5.7 and 5.12, Environmental Consequences

Name: DON C. BAKER

Affiliation: Pacific Northwest National Laboratory

Education:

- B.A., Eastern Washington University

Technical Experience: Database and information technology support (2 years)

EIS Responsibility: Management of Volume II, Public Comment Tracking Database

Name: KENNETH W. BURK

Affiliation: Pacific Northwest National Laboratory

Education:

- B.S., Washington State University (pending)

Technical Experience: Systems and database management, data processing, climatology (5 years)

EIS Responsibility: Generated wind rose figures for Appendix D

Name: WADE P. CARROLL

Affiliation: U.S. Department of Energy

Education:

- M.S., Nuclear Engineering, University of New Mexico, 1975
- B.S., Mechanical and Aerospace Engineering, University of Delaware, 1974

Technical Experience: Nuclear reactor safety, power systems, program management, and program direction (19 years)

EIS Responsibility: National Environmental Policy Act Document Manager

Name: DAVID C. CLOUTIER

Affiliation: Integrated Resources Group, Inc.

Education:

- B.S., Land Use Planning/Biophysical Systems, Northern Michigan University, 1980

Technical Experience: Site characterization investigations, soil and ground remediation projects, and environmental impact (15 years)

EIS Responsibility: Co-authored portions of Section 3

Name: CHRISTOPHER CLUETT

Affiliation: Battelle Seattle Research Center

Education:

- Ph.D., Sociology (Demography), University of Washington, 1977
- M.A., Sociology, University of Washington, 1972
- B.A., English Literature, Williams College, 1963

Technical Experience: Public involvement program planning environmental sociology, socioeconomic impact assessment and demographic analysis (14 years)

EIS Responsibility: Prepared socioeconomics for Oak Ridge area in Section 5

Name: DAVID B. CULPEPPER

Affiliation: Integrated Resources Group, Inc.

Education: • B.S., Physical Geography, Louisiana State University, 1981

Technical Experience: Environmental consultation, project direction, and remedial action (14 years)

EIS Responsibility: Co-authored portions of Section 3

Name: COLBERT E. CUSHING

Affiliation: Pacific Northwest National Laboratory

Education: • Ph.D., Limnology, University of Saskatchewan, 1961
• M.S., Limnology, Colorado State University, 1956
• B.S., Fisheries Management, Colorado State University, 1952

Technical Experience: Freshwater ecological research in streams and radioecology (35 years); more than 21 years of experience in EIS preparation.

EIS Responsibility: Prepared aquatic ecological resources portion of Section 4

Name: PHILIP M. DALING

Affiliation: Pacific Northwest National Laboratory

Education: • B.S., Physical Metallurgy, Washington State University, 1981

Technical Experience: Risk assessment of energy materials transportation systems, including preparation of transportation impact analyses for a wide variety of EISs and EAs

EIS Responsibility: Sections 4 and 5, Transportation

Name: SALVATORE DIMARIA

Affiliation: Battelle - Albuquerque

Education:

- M.A., Geography, University of New Mexico, 1988
- B.S., Biology, University of New Mexico, 1972

Technical Experience: Geographical, biological, and quantitative methods research (7 years)

EIS Responsibility: Prepared the land use and ecological resources portions of Section 4

Name: NANCY D. FOOTE

Affiliation: Pacific Northwest National Laboratory

Education:

- B.A., Sociology and English, University of Missouri, 1952

Technical Experience: Technical writing and editing (20 years)

EIS Responsibility: Editorial and production team lead

Name: CHRISTIAN J. FOSMIRE

Affiliation: Pacific Northwest National Laboratory

Education:

- M.S., Meteorology, Pennsylvania State University, 1993
- B.S., Meteorology, Pennsylvania State University, 1990

Technical Experience: Data collection and analysis in the area of atmospheric diffusion modeling and risk assessment (2 years)

EIS Responsibility: Prepared air quality portion of Section 4

Name: MIKE B. GAVINI

Affiliation: Integrated Resources Group, Inc.

Education:

- Ph.D., Nuclear Chemistry, University of Arkansas
- M.S., Nuclear Chemistry, Andhra University India
- B.S., Chemistry, Physics, and Mathematics, Andhra Christian College, Guntur, India
- Diploma, Direct Marketing, New York University, New York City

Technical Experience: Dosimetry, quality control, nuclear instrumentation, and project management (19 years)

EIS Responsibility: Co-authored portions of Section 3

Name: CLIFFORD S. GLANTZ

Affiliation: Pacific Northwest National Laboratory

Education:

- M.S., Physics and Atmospheric Sciences, University of Washington, 1982
- B.S., Physics and Atmospheric Sciences, State University of New York-Albany, 1979

Technical Experience: Research in environmental risk assessment and risk management, air pollution meteorology, and multipathway pollutant transport modeling (27 years)

EIS Responsibility: Contributed to the air quality portions of Section 4

Name: PATRICIA GODOY-KAIN

Affiliation: Pacific Northwest National Laboratory

Education:

- M.S., Economics, Iowa State University, 1987
- B.A., Economics, Concordia University at Montreal, 1983

Technical Experience: Economic analysis, policy analysis, and economic impact assessments (11 years)

EIS Responsibility: Socioeconomic Impacts and Affected Environment (SNL/NM and LANL)

Name: SHANNON M. GOODWIN

Affiliation: Pacific Northwest National Laboratory

Education:

- M.S., Geology, Western Washington University, 1993
- B.A., Geology, Whitman College, 1985

Technical Experience: Geologic and hydrologic investigations (8 years)

EIS Responsibility: Geology and water resources

Name: GLEN T. HANSON

Affiliation: Battelle - Albuquerque

Education:

- M.A., Anthropology/Archaeology, Arizona State University, 1976
- B.S., Anthropology/Archaeology, Grand Valley State College, 1971

Technical Experience: Environmental and resource management (25 years); regulatory compliance and environmental assessment

EIS Responsibility: Technical reviewer

Name: PAUL L. HENDRICKSON

Affiliation: Pacific Northwest National Laboratory

Education:

- J.D., Law, University of Washington, 1971
- M.S., Industrial Management, Purdue University, 1972
- B.S., Chemical Engineering, University of Washington, 1968

Technical Experience: Energy and environmental studies emphasizing regulatory issues (23 years)

EIS Responsibility: Section 6, Regulatory Requirements

Name: DONNA J. HOSTICK

Affiliation: Pacific Northwest National Laboratory

Education:

- M.S., Agricultural Economics, Purdue University, 1991
- B.A., Economics, Pacific Lutheran University, 1989

Technical Expertise: Compilation of socioeconomic data (3 years); EIS preparation (2 years)

EIS Responsibility: Socioeconomic analysis of INEL Power Burst Facility

Name: LEONARD R. HUESTIES

Affiliation: Pacific Northwest National Laboratory

Education:

- Columbia Basin College, 1991

Technical Experience: Resource management and public relations (20 years)

EIS Responsibility: Build resource library, provide technical support, and data management

Name: KRISHNA R. IYENGAR

Affiliation: Integrated Resources Group, Inc.

Education:

- Ph.D, Nuclear Engineering, Kansas State University, 1973 Registered Professional Engineer (P.E.), State of Alabama
- M.S., Metallurgical Engineering, Montana College of Mineral Science and Technology, 1970
- B. Tech (Honors), Metallurgical Engineering, Indian Institute of Technology, Bombay, India, 1968

Technical Experience: Nuclear engineering, licensing, and reload management (21 years)

EIS Responsibility: Co-authored portions of Section 3

Name: JOHN F. KOTEK

Affiliation: U.S. Department of Energy, Office of Nuclear Energy, Science and Technology

Education:

- B.S., Nuclear Engineering, University of Illinois at Urbana-Champaign, 1989
- M.B.A., University of Maryland at College Park, 1995

Technical Experience: Nuclear facility operations, health physics (6 years)

EIS Responsibility: Authored Section 2, Purpose of and Need for Action

Name: JAY C. LAVENDER

Affiliation: Pacific Northwest National Laboratory

Education:

- B.A., Industrial Technology, Washington State University, 1984

Technical Experience: Safety, reliability, and statistical analysis techniques (11 years)

EIS Responsibility: Transportation analysis for Sections 4 and 5

Name: MARCUS LESTER

Affiliation: Battelle Seattle Research Center

Education:

- M.A., Geography, University of Washington, 1991
- B.A., Geography, University of Washington, 1989

Technical Experience: Geographic, demographic, and quantitative methods research (6 years)

EIS Responsibility: Prepared analyses and maps of minority and low-income populations

Name: MICHAEL D. McKINNEY

Affiliation: Pacific Northwest National Laboratory

Education:

- J.D. College of Law, University of Idaho, 1991
- B.S. Business/Finance, University of Idaho, 1988

Technical Experience: Environmental Law and Policy, Regulatory Analysis, NEPA Document Preparation

EIS Responsibility: Project Manager

Name: EMMETT B. MOORE

Affiliation: Pacific Northwest National Laboratory

Education:

- Ph.D., Physical Chemistry, University of Minnesota, 1956
- B.S., Chemistry, Washington State University, 1951

Technical Experience: Environmental regulation, preparation of environmental documentation (21 years)

EIS Responsibility: Managerial reviewer

Name: IRAL C. NELSON

Affiliation: Pacific Northwest National Laboratory

Education:

- M.A., Physics, University of Oregon, 1955
- B.S., Mathematics, University of Oregon, 1951

Technical Experience: Various aspects of health physics (41 years) and NEPA reviews/documentation (25 years)

EIS Responsibility: Technical reviewer

Name: PAUL R. NICKENS

Affiliation: Pacific Northwest National Laboratory

Education:

- Ph.D., Anthropology, University of Colorado, 1977
- M.A., Anthropology, University of Colorado, 1974
- B.A., Anthropology, University of Colorado, 1969

Technical Experience: Archaeology and historic preservation (22 years).

EIS Responsibility: Prepared the cultural resources portion of Sections 4 and 5

Name: YASUO ONISHI

Affiliation: Pacific Northwest National Laboratory

Education:

- Ph.D., Mechanics and Hydraulics, University of Iowa, 1972
- M.S., Mechanical Engineering, University of Osaka Prefecture, 1969
- B.S., Mechanical Engineering, University of Osaka Prefecture, 1967

Technical Experience: Fluid mechanics and hydrology with expertise in transport and chemical interactions of sediment and contaminants (20 years)

EIS Responsibility: Obtained solubility and adsorption properties of potential contaminants for water resources for Section 5

Name: TED M. POSTON

Affiliation: Pacific Northwest National Laboratory

Education:

- M.S., Fisheries, University of Washington, 1978
- B.A., Biology, Central Washington University, 1973

Technical Experience: Research, environmental assessment, and noise analysis (21 years)

EIS Responsibility: Noise Analysis

Name: KATHLEEN RHOADS

Affiliation: Pacific Northwest National Laboratory

Education:

- M.S., Radiological Sciences, University of Washington, 1979
- B.S., Microbiology, University of Washington, 1972

Technical Experience: Research, environmental health risk assessment (20 years)

EIS Responsibility: Coordinator of consequences analysis for Section 5

Name: STEVEN ROSS

Affiliation: Battelle - Albuquerque

Education:

- M.S., Nuclear Engineering, University of New Mexico, 1987
- B.S., Nuclear Engineering, University of New Mexico, 1985

Technical Experience: Safety analysis, risk assessment, regulatory analysis, and fire risk assessment (9 years)

EIS Responsibility: Contributed to the preparation of Section 3 and the Executive Summary

Name: ROBERT A. SAVOIE

Affiliation: Integrated Resources Group, Inc.

Education:

- M.B.A., Loyola University , New Orleans, 1981
- B.S., Industrial Engineering, Louisiana State University, 1980

Technical Experience: Strategic planning, regulatory licensing/compliance, and public outreach (15 years)

EIS Responsibility: Co-authored portions of Section 3

Name: MICHAEL J. SCOTT

Affiliation: Pacific Northwest National Laboratory

Education:

- Ph.D., Economics, University of Washington, 1975
- M.A., Economics, University of Washington, 1971
- B.A., Economics, Washington State University, 1970

Technical Experience: Assessing socioeconomic impact of major projects and social policies (20 years)

EIS Responsibility: Socioeconomics and Environmental Justice sections

Name: B. P. SINGH

Affiliation: Integrated Resources Group, Inc.

Education:

- M.S. Mechanical Engineering, University of Maryland, 1978
- B. Tech., Aeronautical Engineering, Indian Institute of Technology, Kanpur, India, 1975

Technical Experience: Design, analysis, quality assurance, and licensing of commercial nuclear power plants, safety analyses of nuclear facilities, and project management (20 years)

EIS Responsibility: Co-authored portions of Section 3

Name: RICHARD I. SMITH

Affiliation: Pacific Northwest National Laboratory

Education:

- B.S., Physics, Washington State University, 1955
- M.S., Applied Physics, University of California at Los Angeles, 1957
- P.E., Nuclear Engineering (State of Washington, 1972)
- P.E., Nuclear Engineering (State of California, 1975)

Technical Experience: Reactor neutronics, decommissioning analyses, spent fuel storage, systems engineering (38 years)

EIS Responsibility: Section 5.22, Comparison of Alternative Costs

Name: LISSA STAVEN

Affiliation: Pacific Northwest National Laboratory

Education:

- M.S., Health Physics, Colorado State University, 1990
- B.S., Environmental Conservation, University of New Hampshire, 1984

Technical Experience: Environmental health physics and low-level waste disposal management practices (6 years)

EIS Responsibility: Section 5, Radiological Accident Consequences and Air Quality

Name: ROBERT J. TALBERT

Affiliation: Pacific Northwest National Laboratory

Education:

- M.S., Nuclear Engineering, University of Michigan, 1976
- B.S., Engineering Physics, University of Michigan, 1975
- PE Mechanical Engineering (Washington, 29904)
- PE Nuclear Engineering (Washington, 29904)
- Senior Reactor Operator License (AEC) 1296-1

Technical Experience: Performed first reactor criticality (1963); varied capacities in the nuclear industry (34 years)

EIS Responsibility: Section 3, Alternatives

Name: TOMMYE S. WRIGHT

Affiliation: Pacific Northwest National Laboratory

Education: B.S., Oklahoma State University, 1978

Technical Experience: Occupational safety and health, including safety audits, radiation protection, construction, and training (17 years)

EIS Responsibility: Section 3, Alternatives

9.0 Bibliography

- 10 CFR 71. 1993. "Packaging and Transportation of Radioactive Material." *U.S. Code of Federal Regulations*. U.S. Nuclear Regulatory Commission, Washington, D.C.
- 40 CFR 50. 1991. "National Primary and Secondary Ambient Air Quality Standards." *U.S. Code of Federal Regulations*. Office of the Federal Register, Washington, D.C.
- 40 CFR 61, Subpart H. 1989. "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities." Clean Air Act Amendments. *U.S. Code of Federal Regulations*. Office of the Federal Register, Washington, D.C.
- 40 CFR 81.329. 1993. "Designation of Areas for Air Quality Planning Purposes, Subpart C, Section 107 Attainment Status Designations, Nevada." *U.S. Code of Federal Regulations*. Office of the Federal Register, Washington, D.C.
- 49 CFR 173. 1993. "Shippers - General Requirements for Shipments and Packages." *U.S. Code of Federal Regulations*. U.S. Department of Transportation, Washington, D.C.
- 49 CFR 173.403 (bb). 1994. "Definitions (Transport Index)." *U.S. Code of Federal Regulations*. Research and Special Programs Administration, U.S. Department of Transportation, Washington, D.C.
- 49 CFR 175. 1994. "Carriage by Aircraft." *U.S. Code of Federal Regulations*. Research and Special Programs Administration, U.S. Department of Transportation, Washington, D.C.
- Aerojet Nuclear Company (ANC). 1971. *Final Safety Analysis Report of the Power Burst Facility*, ANCR-1011. US Atomic Energy Commission, Idaho Operations Office under Contract No. AT-(10-1)-1375, Idaho Falls, Idaho.
- | American Cancer Society. 1994. "Cancer Facts and Figures 1994." American Cancer Society, Atlanta,
| Georgia.
- Anderson, J. E. 1991. *Final Report: Vegetation Studies to Support the NPR Environmental Impact Statement*. Subcontract No. C34-110421, Task Order No. 72, EG&G Idaho, Inc., Idaho Falls, Idaho.
- Andrade, A. 1995. *Stress-Assisted, Microbial-Induced Corrosion of Stainless Steel Primary Piping and Other Aging Issues at The Omega West Reactor*. LA-UR-95-1618, Los Alamos National Laboratory, Los Alamos, New Mexico.

Argonne National Laboratory (ANL). 1991. *Environmental Site Description for a Uranium Atomic Vapor Laser Isotope Separation (U-AVLIS) Production Plant at the Oak Ridge Gaseous Diffusion Plant Site*. ANL/EAIS/TM-58, U.S. Department of Energy, Environmental Assessment and Information Sciences Division, Chicago, Illinois.

Arthur, W. J., J. W. Connelly, D. K. Halford, and T. D. Reynolds. 1984. *Vertebrates of the Idaho National Engineering Laboratory*. DOE/ID-12099, U.S. Department of Energy, Idaho Falls, Idaho.

Barclay, L. A. 1990. U.S. Fish and Wildlife Service, letter to R. L. Kroodsma of Oak Ridge Reservation Resources Management Organization, ORNL, regarding "Construction - related loss of fish and wildlife habitat on ORNL lands," June 13.

Barclay, L. A. 1992. U.S. Fish and Wildlife Service, letter to R. L. Kroodsma of Oak Ridge Reservation Resources Management Organization, ORNL, regarding "Updated Threatened and Endangered Species Information for the Oak Ridge Reservation," July 20.

Bay, R. T. 1991. U.S. Fish and Wildlife Service, letter to R. L. Kroodsma of Oak Ridge Reservation Resources Management Organization, ORNL, regarding "Updated Threatened and Endangered Species Information for the Oak Ridge Reservation," March 7.

Beavers, J. E., et al. 1982. *Recommended Seismic Hazard Levels for the Oak Ridge, Tennessee; Paducah, Kentucky; Fernald, Ohio; and Portsmouth, Ohio, Department of Energy Reservation*. K/BD-1025/R1, Union Carbide Corporation, Oak Ridge, Tennessee.

Becker, N. M. 1991. *Influence of Hydraulic and Geomorphologic Components of a Semi-Arid Watershed on Depleted Uranium Transport*. Doctoral Dissertation. Department of Civil and Environmental Engineering, University of Wisconsin, Madison, Wisconsin.

Beres, D. A. 1990. *The Clean Air Act Assessment Package-1988 (CAP-88): A Dose and Risk Assessment Methodology for Radionuclide Emissions to Air*. Volumes 1-3. SC&A Inc., McLean, Virginia.

Binford, F. T., R. S. Stone, and C. C. Webster. 1968. *The Oak Ridge Research Reactor - Safety Analysis*. ORNL-4169, Vol. 2. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Bowen, B. M. 1990. *Los Alamos Climatology*. LA-11735-MS. Los Alamos National Laboratory Report, Los Alamos, New Mexico.

Boyle, J. W., R. Blumberg, S. J. Cotter, G. S. Hill, C. R. Kerley, R. H. Ketelle, R. L. Kroodsma, D. W. Lee, R. C. Martin, R. D. Roop, D. N. Secora, W. P. Staub, and R. E. Thoma. 1982. *Environmental Analysis of the Operation of the Oak Ridge National Laboratory (X-10 Site)*. ORNL-5870, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Butz, T. R. 1984. *Resource Management Plan for the U.S. Department of Energy Oak Ridge Reservation, Volume 8, Appendix H: Geology*. ORNL-6026, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Chowlewa, A. F., and D. M. Henderson. 1984. *A Survey and Assessment of the Rare Vascular Plants of the INEL*. DOE/ID-12100, U.S. Department of Energy, Idaho Operations Office, Radiological and Environmental Sciences Laboratory, Idaho Falls, Idaho.

Clarke, R. K., J. T. Foley, W. F. Hartman, and D. W. Larson. 1976. *Severities of Transportation Accidents, Volume 1 - Summary*. SLA-74-001, Sandia National Laboratories, Albuquerque, New Mexico.

Clawson, K. L., G. E. Start, N. R. Ricks. 1989. *Climatology of the Idaho National Engineering Laboratory*. 2nd Edition. DOE/ID-12118. Idaho Falls, Idaho.

Clean Air Act (CAA). 1990. Public Law 101-549, as amended, 42 USC 7401 et seq.

Coats, D. W., and R. C. Murray. 1984. *Natural Phenomena Hazards Modeling Project: Seismic Hazard Models for Department of Energy Sites*. UCRL-535821, Rev. 1, Lawrence Livermore National Laboratory, University of California, Livermore, California.

Commerce Business Daily (CBD). 1995. "Potential Sources Sought." Issue No. PSA-1454, dated October 18, 1995.

Critchfield, H. J. 1974. *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Cross, S. 1994. *Aquatic Macroinvertebrates and Water Quality of Sandia Canyon, Los Alamos National Laboratory, December 1992-October 1993*. LA-12734-SR, Los Alamos National Laboratory, Los Alamos, New Mexico.

Culp, T., W. Cox, H. Hwang, M. Irwin, A. Jones, B. Matz, K. Molley, W. Rhodes, D. Stermer, and T. Wolff. 1992. *1991 Environmental Monitoring Report Sandia National Laboratories, Albuquerque, New Mexico*. SAND92-0939, Sandia National Laboratories, Albuquerque, New Mexico.

Culp, T., W. Cox, H. Hwang, M. Irwin, A. Jones, B. Matz, K. Molley, W. Rhodes, D. Stermer, and T. Wolff. 1993. *1992 Environmental Monitoring Report Sandia National Laboratories, Albuquerque, New Mexico*. SAND93-1448, Sandia National Laboratories, Albuquerque, New Mexico.

Culp, T., W. Cox, H. Hwang, M. Irwin, A. Jones, B. Matz, K. Molley, W. Rhodes, D. Stermer, and T. Wolff. 1994. *1993 Environmental Monitoring Report Sandia National Laboratories, Albuquerque, New Mexico*. SAND94-1293. Sandia National Laboratories, Albuquerque, New Mexico.

Cunningham, M., and L. Pounds. 1991. *Resource Management Plan for the Oak Ridge Reservation, Volume 228: Wetlands on the Oak Ridge Reservation*. ORNL/NERP-5, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Cunningham, M., L. Pounds, S. Oberholster, P. Parr, L. Edwards, B. Rosensteel, and L. Mann. 1993. *Resource Management Plan for the Oak Ridge Reservation, Volume 29: Rare Plants on the Oak Ridge Reservation*, ORNL/NERP-7, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Dennis, A. W., J. T. Foley, W. F. Hartman, and D. W. Larson. 1978. *Severities of Transportation Accidents Involving Large Packages*. SAND77-0001, Sandia National Laboratories, Albuquerque, New Mexico.

Dunham, D. A. 1995. *Draft Biological and Floodplain/Wetland Assessment for Environmental Restoration Program, Operable Unit 1086, TA-15*. LA-UR-95-649, Los Alamos National Laboratory, Los Alamos, New Mexico

East Tennessee Development District. 1995a. *County Data Sheets: Economic Statistics*. (Winter). East Tennessee Development District, Knoxville, Tennessee.

East Tennessee Development District. 1995c. "Economic Statistics." Tennessee Department of Revenue, Knoxville, Tennessee.

East Tennessee Development District. 1995b. "Economic Statistics." Tennessee Department of Employment Security, Knoxville, Tennessee.

Eastern Environmental Radiation Facility. 1989. *Environmental Radiation Data*. Reports 57-59, Eastern Environmental Radiation Facility, Montgomery, Alabama.

EG&G. 1987. *Environmental Assessment: Fuel Processing Restoration at the Idaho National Engineering Laboratory*. DOE/EA-0306, EG&G Idaho, Inc., Idaho Falls, Idaho.

Executive Order 12898. February 11, 1994. "Federal Actions to Address Environmental Justice to Minority Populations and Low-Income Populations." 59 FR 7629, February 16, 1994, *Federal Register*.

Fischer, L. F., C. K. Chou, M. A. Gerhard, C. Y. Kimura, R. W. Martin, R. W. Mensing, M. E. Mount, and M. C. Witte. 1987. *Shipping Container Response to Severe Highway and Railway Accident Conditions*. NUREG/CR-4829, U.S. Nuclear Regulatory Commission, Washington, D.C.

Fischer, N. T. 1990. *Revision of Species Inventory Checklists for Sandia National Laboratories, Albuquerque, Bernalillo County, New Mexico*: Final Report. Sandia National Laboratories, Albuquerque, New Mexico.

Gilmore, J. S., and M. K. Duff. 1975. *Boom Town Growth Management: A Case Study of Rock Springs-Green River Wyoming*. Westview Press, Boulder, Colorado.

Hackett, W. R., and R. P. Smith. 1992. *Quaternary Volcanism, Tectonics, and Sedimentation in the Idaho National Engineering Laboratory Area*. EGG-M-92071, EG&G Idaho, Idaho Falls, Idaho.

Hampton, N. L., R. C. Rope, J. M. Glennon, and K. S. Moor. 1993. *A Preliminary Survey of Designated Wetlands on the Idaho National Engineering Laboratory*. EGG-EEL-10629, EG&G Idaho, Idaho Falls, Idaho.

Hardy, C. L. 1991. Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, memorandum to R. Kroodsma, Oak Ridge National Laboratory, regarding "Observations of Nesting Black Vultures on the ORR," April 18.

Hardy, C. L., L. R. Pounds, and R. Cook. 1992. *Results of the Y-12 Area Rare Plant and Wetland Survey, Environmental Sciences Division*. National Environmental Research Park, Oak Ridge, Tennessee.

Hatcher, R. D. Jr., P. J. Lemiszki, R. B. Dreier, R. H. Ketelle, R. R. Lee, D. A. Leizke, W. M. McMaster, J. L. Foreman, and S. Y. Lee. 1992. *Status Report on the Geology of the Oak Ridge Reservation*. ORNL/TM-12074, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Holdren, G. R., C. S. Glantz, L. K. Berg, K. Delinger, S. M. Goodwin, J. R. Rustad, R. Schalla, J. A. Shramke. 1994. *Environmental Settings for Selected U.S. Department of Energy Installations: Support Information for the Programmatic Environmental Impact Statement*. PNL-10180, Pacific Northwest Laboratory, Richland, Washington.

Homer, R. N., W. G. Reed, J. W. Ross, and B. L. Ringe. 1987. *Archeological Investigations on the Idaho National Engineering Laboratory, 1984-1985*. Idaho State University, Pocatello, Idaho.

Idaho Power Company/U.S. Department of Energy (IPC/DOE). 1986. "Contract for Electric Service between Idaho Power Company and United States Department of Energy Idaho Operations Office." Contract No. DE-AC07-86ID12588, effective date November 1, 1986.

International Commission on Radiological Protection (ICRP). 1979-1982. Limits for Intakes of Radionuclides by Workers. ICRP Publication 30, Pergamon Press, New York, New York: Part 1 - Annals of the ICRP Vol. 2, No. 3-4 (1979a), Supplement to Part 1 - Annals of the ICRP Vol. 3, No. 1-4 (1979); Part 2 - Annals of the ICRP Vol. 4, No. 3-4 (1980), Supplement to Part 2 - Annals of the ICRP Vol. 5 (1981); Part 3 - Including Addendum to Parts 1 and 2 - Annals of the ICRP Vol. 6, No. 2-3 (1981), Supplement A to Part 3 - Annals of the ICRP Vol. 7, No. 1-3 (1982), Supplement B to Part 3 - Including Addendum to the Supplements of Parts 1 and 2 - Annals of the ICRP Vol. 8 (1982); Index to the ICRP Publication No. 3 - Annals of the ICRP Vol. 8, No. 4 (1982).

- International Commission on Radiological Protection (ICRP). 1991. *1990 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 60, Pergamon Press, Oxford.
- Jardine, D. 1995. *Acid Deposition and Visibility Measurements*. LANL Letter No. ESH-17:95-217, March 24, Los Alamos National Laboratory, Los Alamos, New Mexico.
- Joy, D. S., and P. E. Johnson. 1992. *HIGHWAY 5.0, A Transportation Routing Model: Program Description and Revised User's Manual*. ORNL/TM-8759, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Kitchings, J. T., and J. D. Story. 1984. *Resource Management Plan for U.S. Department of Energy, Oak Ridge Reservation, Volume 16, Appendix Q: Wildlife Management*. ORNL 6026/V16, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Kornegay, F. C., D. C. West, L. W. McMahon, J. B. Murphy, L. G. Shipe, and W. S. Koncinski. 1993. *Oak Ridge Reservation Environmental Report for 1992*. ES/ESH-31/V1, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Kramber, W. L., R. C. Rope, J. Anderson, J. Giennon, and A. Morse. 1992. "Producing a Vegetation Map of the Idaho National Engineering Laboratory Using Landsat Thematic Mapper Data." In *Proceedings of the ASPRS 1992 Annual Meeting*. Albuquerque, New Mexico.
- Kroodsma, R. L. 1987. *Resource Management Plan for the Oak Ridge Reservation, Volume 24: Threatened and Endangered Animal Species*. ORNL/ESH-1/V24, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Kuntz, M. A., B. Skipp, M. A. Lanphere, W. E. Scott, K. L. Pierce, G. Dalrymple, L. A. Morgan, D. E. Champion, G. R. Embree, R. P. Smith, W. R. Hackett, and D. W. Rodgers. 1990. *Revised Geologic Map of the INEL and Adjoining Areas, Eastern Idaho*. Open-File Report 990-333, U.S. Geological Survey, Idaho Falls, Idaho.
- Lawrence Livermore National Laboratory (LLNL). 1990. *Assessment of Potential Volcanic Hazards for New Production Reactor Site at the Idaho National Engineering Laboratory*. NPR91-029-DHC, Volcanism Working Group, Lawrence Livermore National Laboratory, Livermore, California.
- Loar, J. M (ed.). 1994. *Fourth Report on the Oak Ridge National Laboratory Biological Monitoring and Abatement Program for White Oak Creek Watershed and the Clinch River*. ORNL/TM-11544, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Loar, J. M., J. A. Solomon, and G. F. Cada. 1981. *Technical Background Information for the ORNL Environmental and Safety Report, Volume 2: A Description of the Aquatic Ecology of White Oak Creek Watershed and the Clinch River Below Melton Hill Dam*. ORNL/TM-7509/V2, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Los Alamos National Laboratory (LANL). 1992a. *Installation Work Plan for Environmental Restoration*. LA-UR-92-3795, Rev. 2, Los Alamos National Laboratory, Los Alamos, New Mexico.

Los Alamos National Laboratory (LANL). 1992b. *RFI Work Plan for Environmental Restoration*. LA-UR-92-855, Rev. 2, Los Alamos National Laboratory, Los Alamos, New Mexico.

Los Alamos National Laboratory (LANL). 1993a. *RFI Work Plan for Operable Unit 1098*. LA-UR-92-3825, Environmental Restoration Group, Los Alamos National Laboratory, Los Alamos, New Mexico.

Los Alamos National Laboratory (LANL). 1993b. *TA-2I Operable Unit RCRA Facility Investigation Phase Report IA*. LA-UR-93-2028, Environmental Restoration Program, Los Alamos National Laboratory, Los Alamos, New Mexico.

Los Alamos National Laboratory (LANL). 1993c. *RFI Work Plan for Operable Unit 1114*. LA-UR-93-1000, Environmental Restoration Group, Los Alamos National Laboratory, Los Alamos, New Mexico.

Los Alamos National Laboratory (LANL). 1993d. *Installation Work Plan for Environmental Restoration Program*, Rev. 3. LA-UR-93-3987, Los Alamos National Laboratory, Los Alamos, New Mexico.

Los Alamos National Laboratory (LANL). 1993e. *Environmental Assessment -- Medical Radioisotope Production at Los Alamos Combined Draft Molybdenum-99 and Iodine-125 Products (Revision 2) Technical Area-2, Omega West Reactor, and Technical Area-3, Chemistry Metallurgy Research Building*. LA-UR-4289, Los Alamos National Laboratory, Los Alamos, New Mexico.

Los Alamos National Laboratory (LANL). 1994a. *Environmental Surveillance at Los Alamos During 1992*. LA-12764-ENV, Los Alamos National Laboratory, Los Alamos, New Mexico.

Los Alamos National Laboratory (LANL). 1994b. *Environmental Assessment for Medical Radioisotope Production at Los Alamos, Combined Draft Molybdenum-99 and Iodine-125 Projects*. LAN-92-053, Rev. 2, Los Alamos National Laboratory, Los Alamos, New Mexico.

Los Alamos National Laboratory (LANL). 1995. *U.S. Department of Energy Air Emissions Report, 1994 LANL Dose*. Los Alamos National Laboratory, Los Alamos, New Mexico.

Los Alamos Technical Associates (LATA). 1991. *AIRDOS-EPA Data Upgrade and Dose Calculations for Sandia National Laboratories Facilities at Sandia, and Sandia, Tonopah Test Range*. Prepared for Sandia National Laboratories, Albuquerque, New Mexico.

Madsen, M. M., E. L. Wilmot, and J. M. Taylor. 1983. *RADTRAN II User's Guide*. SAND82-2681, Sandia National Laboratories, Albuquerque, New Mexico.

Madsen, M. M., J. M. Taylor, R. M. Ostmeyer, and P. C. Reardon. 1986. *RADTRAN III*. SAND84-0036, Sandia National Laboratories, Albuquerque, New Mexico.

Martin Marietta Energy Systems, Inc. (MMES). 1989a. *Oak Ridge Reservation Site Development and Facilities Utilization Plan*. DOE/OR-885, (89), U.S. Department of Energy, Oak Ridge, Tennessee.

Martin Marietta Energy Systems, Inc. (MMES). 1989b. *Oak Ridge Reservation Environmental Report for 1988, Volume 1: Narrative, Summary, and Conclusions*. ES/ESH-8/V1, Environmental and Safety Activities, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

Martin Marietta Energy Systems, Inc. (MMES). 1992. *Oak Ridge Reservation Environmental Report for 1991*. ES/ESH-22/VI, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

Martin Marietta Energy Systems, Inc. (MMES). 1993. *Oak Ridge Reservation Environmental Report for 1992, Volumes 1 and 2*. ES/ESH-31, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

Martin Marietta Energy Systems, Inc. (MMES). 1994. *Oak Ridge Reservation Technical Site Information*. ES/EN/SFP-23, Site and Facilities Planning Department, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

Massey, C. D., D. L. Miller, S. D. Carson, T. A. Wheeler, S. W. Longley, R. L. Coats, E. J. Parma, M. McDonald, M. E. Vernon, S. C. Bourcier, S. G. Mills, A. J. Trennel, and K. R. Boldt. 1995. *Feasibility Study of Medical Isotope Production at Sandia National Laboratories*. SAND 95-2703, Sandia National Laboratories, Albuquerque, New Mexico.

McCord, J. P., J. T. McCord, J. D. Gibson, and H. L. King, eds. 1993. *Sandia National Laboratories Site-Wide Hydrogeological Characterization Project Calendar Year 1992 Annual Report*. U.S. Department of Energy Albuquerque Operations Office, Albuquerque, New Mexico.

McLin, S. G. 1993. *Analysis of Rockfall Hazards at Los Alamos National Laboratory*. Submitted to the Fourth DOE Natural Phenomena Hazards Mitigation Conference, Atlanta, Georgia. LA-UR-93-3007, Los Alamos National Laboratory, Los Alamos, New Mexico.

Mitchell, R. G. 1994. *The Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1993*. DOE/ID-12082(93), Idaho National Engineering Laboratory, Idaho Falls, Idaho.

Morris, R. C. 1993. "The Implications of Lined Radioactive Waste Ponds for Waterfowl Contamination," in *Environmental Health Physics, Proceedings of the Twenty-Sixth Midyear Topical Meeting of the Health Physics Society, Coeur d'Alene, January 24-28, 1993*, R. L. Kathren, D. H. Denham, K. Salmon, eds., Richland, Washington: Columbia Chapter, Health Physics Society, pp. 147-155.

Napier, B. A., D. L. Streng, R. A. Peloquin, and J. V. Ramsdell. 1988. *GENII - The Hanford Environmental Radiation Dosimetry Software System*. PNL-6584, Vol. 1 - Conceptual Representation, Vol. 2 - Users' Manual, Vol. 3 - Code Maintenance Manual. Pacific Northwest Laboratory, Richland, Washington.

National Council on Radiation Protection and Measurement (NCRP). 1987. *Ionizing Radiation Exposure of the Population of the United States*. NCRP Report No. 93, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

National Research Council, Committee on the Biological Effects of Ionizing Radiations (BEIR). 1990. *Health Effects of Exposure to Low Levels of Ionizing Radiation*. BEIR V. National Academy Press, Washington, D.C.

Neuhauser, K. S., and F. L. Kanipe. 1992. *RADTRAN 4: Volume 3 -- User Guide*. SAND89-2370, Sandia National Laboratories, Albuquerque, New Mexico.

New Mexico State Department of Labor. 1994. 1993-1994, *Covered Employment and Wages*, First Quarter 1993 (October 1993), Second Quarter 1993 (March 1994), Third Quarter 1993 (August 1994), Fourth Quarter (September 1994). New Mexico State Department of Labor, Santa Fe, New Mexico.

Nucleonics Week. 1996. Volume 37(5), February 1, 1996.

Nyhan, J. W., L. W. Hacker, T. E. Calhoun, and D. L. Youngt. 1978. *Soil Survey of Los Alamos County, New Mexico*. LA-6779-MS, UC-11, Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico.

Oak Ridge Chamber of Commerce. 1995. *An Introduction to a Technology Community*. Oak Ridge Chamber of Commerce, Oak Ridge, Tennessee.

Oak Ridge National Laboratory (ORNL). 1981. *Environmental and Safety Report for Oak Ridge National Laboratory*. ORNL-SUB-41B-38403C, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Oak Ridge National Laboratory (ORNL). 1988. *Data Package for the Low-Level Waste Disposal Development and Demonstration Program, Environmental Impact Statement*. ORNL/TM-10939/V1, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

- Parr, P. D., and J. W. Evans. 1992. *Draft Resource Management Plan for the Oak Ridge Reservation, Wildlife Management Plan*. ORNL/NERP-6, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Parr, P. D., and L. R. Pounds. 1987. *Resource Management Plan for the Oak Ridge Reservation*. ORNL/ESH-1/V23, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Peterson, E. J. 1995. *Omega West Reactor - Fission Product Isotope Production Program*. Submitted to the Annual Meeting of the American Nuclear Society, Philadelphia, Pennsylvania, June 25-29, 1995.
- Pounds, L. R., P. D. Parr, and M. G. Ryon. 1993. *Resource Management Plan for the Oak Ridge Reservation, Volume 30: Oak Ridge National Environmental Research Park Natural Areas and Reference Areas - Oak Ridge Reservation Environmentally Sensitive Sites Containing Special Plants, Animals and Communities*. ORNL/NERP-8, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Rao, R. K., E. L. Wilmot, and R. E. Luna. 1982. *Non-Radiological Impacts of Transporting Radioactive Material*, SAND81-1703, Sandia National Laboratories, Albuquerque, New Mexico.
- Reynolds, T. D., J. W. Connelly, D. K. Halford, and W. J. Arthur. 1986. "Vertebrate Fauna of the Idaho National Environmental Research Park." *Great Basin Naturalist* 46:513-527.
- Risberg, D. 1995. *Biological and Floodplain/Wetland Assessment for the Dual-Axis Radiographic Hydrodynamics Test Facility (DARHT)*. LAUR-95-647, Los Alamos National Laboratory, Los Alamos, New Mexico.
- Rojas-Burke, J. 1995. "The Future Supply of Molybdenum-99." *J. Nucl. Med.* 36:15N-22N (Newsline).
- Rope, R. C., N. L. Hampton, and K. A. Finley. 1993. "Ecological Resources" in Irving, J. S., Environmental Resource Document for the Idaho National Engineering Laboratory, Volumes I and II. EGG-WMD-10279, EG&G Idaho, Inc., Idaho Falls, Idaho.
- Sameth, A. A., and J. A. Hans. 1987. "Production Techniques of Fission Molybdenum-99." *Radiochimica Acta*. 41:65-72.
- Sandia National Laboratories-Albuquerque (SNLA). 1987. *Comprehensive Environmental Assessment and Response Program, Phase 1: Installation Assessment, Sandia National Laboratories - Albuquerque (DRAFT)*. SA-0006\S, Sandia National Laboratories, Albuquerque, New Mexico.
- Sandia National Laboratories-Albuquerque (SNLA). 1990. *Phase I Investigation Report for the Mixed Waste Landfill*. Rept. 01-90, Rev. 0, Sandia National Laboratories, Environmental Restoration Programs Project Group, Albuquerque, New Mexico.

Sandia National Laboratories-Albuquerque (SNLA). 1993a. *Site-Wide Hydrogeologic Characterization Project, CY 1992 Annual Report*. Sandia National Laboratories, Environmental Restoration Programs, Albuquerque, New Mexico.

Sandia National Laboratories-Albuquerque (SNLA). 1993b. *Draft Report of Technical Areas 3 and 5 RCRA Facility Investigation Work Plan*. Plan 93-05, Rev. 0, Sandia National Laboratories, Environmental Restoration Programs, Albuquerque, New Mexico.

Sandia National Laboratories-Albuquerque (SNLA). 1993c. *Septic Tanks and Drainfields (ADS-1295) RCRA Facility Investigation Work Plan*. Plan 92-17, Sandia National Laboratories, Environmental Restoration Programs, Albuquerque, New Mexico.

Saricks, C., and T. Kvitek. 1994. *Longitudinal Review of State-Level Accident Statistics for Carriers of Interstate Freight*. ANL/ESD/TM-68, Argonne National Laboratory, Argonne, Illinois.

Savoie, R. A., and B. P. Singh. 1994. *Independent Assessment of the DOE Plan to Establish a United States Production Source for Molybdenum-99*. U.S. Department of Energy, Office of Nuclear Energy Isotope Production and Distribution Program, Washington, D.C.

Senate Report 103-291. 1994. Energy and Water Development Appropriation Bill, 1995. Senate Committee on Appropriations, Washington, D.C.

Senior Scientists and Engineers. 1995. *Study Report to the United States House of Representatives Committee on Science Subcommittee on Energy and Environment on the Department of Energy's Isotope Production and Distribution Program*. Senior Scientists and Engineers, Volunteer Organization Committee, American Association for the Advancement of Science, Washington, D.C.

Smith, T. W., and M. E. Bunker. 1989. *Omega West Reactor (OWR) Safety Analysis Report*. Los Alamos National Laboratory, Los Alamos, New Mexico.

Solomon, D. K., K. Moore, L. E. Toran, R. B. Dreier, and W. M. McMaster. 1992. *Status Report: A Hydrologic Framework for the Oak Ridge Reservation*. ORNL/TM-12026, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Taylor, J. M., and S. L. Daniel. 1982. *RADTRAN II: A Revised Computer Code To Analyze Transportation of Radioactive Material*. SAND80-1943, Sandia National Laboratories, Albuquerque, New Mexico.

Teel, D. M. 1993. *Utilities and Energy*. Engineering Design File ER&WM-EDF-0019-93, EG&G Idaho, Inc., Idaho Falls, Idaho.

Tennessee Department of Environmental and Conservation (TDEC). 1992a. *Federal and State Ranks Tennessee Rare Vertebrates*. Tennessee Department of Environment and Conservation, Division of Ecological Services, Nashville, Tennessee.

Tennessee Department of Environment and Conservation (TDEC). 1992b. *Federal and State Ranks, Tennessee Rare Invertebrates*. Tennessee Department of Environment and Conservation, Nashville, Tennessee.

Tennessee Department of Environment and Conservation (TDEC). 1992c. *Rare Plant List of Tennessee*. Tennessee Department of Environment and Conservation, Nashville, Tennessee.

Tennessee Department of Environment and Conservation (TDEC). 1992d. *Tennessee County Distribution Records for Endangered, Threatened, and Status Review Species*. Tennessee Department of Environment and Conservation, Nashville, Tennessee.

Tennessee Wildlife Resources Commission (TWRC). 1991. *Proclamation - Wildlife in Need of Management, Amended by Proclamation 91-4*. Tennessee Wildlife Resources Commission, Nashville, Tennessee.

Travis, J. R. 1992. *Atlas of the Breeding Birds of Los Alamos County, New Mexico*. LA-12206, Los Alamos National Laboratory, Los Alamos, New Mexico.

University of Missouri. 1994. *University of Missouri Research Reactor 1994 Annual Report*. University of Missouri, Columbia, Missouri.

U.S. Corps of Engineers (COE). 1987. *Corps of Engineers Wetland Delineation Manual*. Technical Report 4-87-1, Waterways Experiment Station, Vicksburg, Mississippi.

U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS). 1977. *Soil Survey of Bernalillo County and Parts of Sandoval and Valencia Counties, New Mexico*. U.S. Department of Agriculture and U.S. Department of the Interior, Washington, D.C.

U.S. Department of Commerce (DOC). 1986. *Regional Multipliers: A User Handbook for the Regional Input-Output Modeling System - RIMS II*. BEAREA8601, NTIS, Springfield, Virginia.

U.S. Department of Commerce (DOC). 1987a. *Local Climatological Data Annual Summaries for 1986 Part II Southern Region*. National Oceanic Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.

U.S. Department of Commerce (DOC). 1987b. *Local Climatological Data Annual Summaries for 1986 Part III Central Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.

- U.S. Department of Commerce (DOC). 1987c. *Local Climatological Data Annual Summaries for 1986 Part IV Western Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- U.S. Department of Commerce (DOC). 1994a. *Regional Economic Information System*. Bureau of Economic Analysis, U.S. Department of Commerce, Washington, D.C.
- U.S. Department of Commerce (DOC). 1994b. *County and City Data Book: 1994*. U.S. Department of Commerce, Bureau of the Census, Washington, D.C.
- U.S. Department of Commerce (DOC). 1995. *Regional Economic Information System*. Economics and Statistics Administration, Bureau of Economic Analysis, Regional Economic Measurement Division, U.S. Department of Commerce, Washington, D.C.
- U.S. Department of Energy (DOE). 1979. *Final Environmental Impact Statement, Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico*. DOE/EIS-0018, U.S. Department of Energy, Washington, D.C.
- U.S. Department of Energy (DOE). 1981. Environmental Protection, Safety, and Health Protection Information Reporting Requirements. U.S. DOE Order 5484.1 (1982). U.S. Department of Energy, Washington, D.C.
- U.S. Department of Energy (DOE). 1987. *Environmental Assessment: Fuel Processing Restoration at the Idaho National Engineering Laboratory*. DOE/EA-0306, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho.
- U.S. Department of Energy (DOE). 1988a. *Environmental Survey Preliminary Report, Sandia National Laboratories*. DOE/EH/OEV-18-P, U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico.
- U.S. Department of Energy (DOE). 1988b. "General Environmental Protection Program." DOE Order 5400.1, U.S. Department of Energy, Office of Environment, Safety and Health, Washington, D.C.
- U.S. Department of Energy (DOE). 1988c. *Historical Radionuclide Releases from Current DOE Oak Ridge Operations Office Facilities*. OR-890. U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tennessee.
- U.S. Department of Energy (DOE). 1990. "Radiation Protection of the Public and Environment." DOE Order 5400.5, U.S. Department of Energy, Office of Environment, Safety and Health, Washington, D.C.

U.S. Department of Energy (DOE). 1990. *Environmental Assessment for Process Equipment Waste and Process Waste Liquid Collection Systems*. DOE/EA-0437, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho.

U.S. Department of Energy (DOE). 1991a. *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*. DOE/EH-0173T, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1991b. *Draft Environmental Impact Statement for the Siting, Construction, and Operation of New Production Reactor Capacity, Vol. 4*. DOE/EIS-044D, U.S. Department of Energy, Office of Production Reactors, Washington, D.C.

U.S. Department of Energy (DOE). 1992a. "Safety Analysis Report." DOE Order 5480.23, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1992b. "Nuclear Technical Safety Requirements." DOE Order 5480.22, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1992c. "Conduct of Operations Requirements for DOE Facilities." DOE Order 5480.19, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1993a. *Nonnuclear Consolidation Environmental Assessment, Volume 1: Nuclear Weapons Complex Reconfiguration Program*. DOE/EA-0792, U.S. Department of Energy, Office of Defense Programs, Deputy Assistant Secretary for Weapons Complex Reconfiguration, Washington, D.C.

U.S. Department of Energy (DOE). 1993b. *INEL Technical Site Information Report*. DOE/ID-10401, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho.

U.S. Department of Energy (DOE). 1993c. *Spent Fuel Working Group Report on Inventory and Storage of the Department's Spent Nuclear Fuel and Other Reactor Irradiated Nuclear Materials and Their Environmental, Safety and Health Vulnerabilities*. U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1994a. *U.S. Department of Energy National Isotope Strategy (DOE/NE-0111)*. U.S. Department of Energy, Isotope Production and Distribution Program, Washington, D.C.

U.S. Department of Energy (DOE). 1994b. *Integrated Data Base Report-1993: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*. Prepared by Oak Ridge National Laboratory. DOE/RW-006, Rev. 10, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1994c. *Environmental Assessment Reracking of High Flux Isotope Reactor (HFIR) Spent Fuel Assemblies*. DOE/EA-0935, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

U.S. Department of Energy (DOE). 1994d. *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*. DOE-STD-1020-94, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1994e. *Environmental Checklist/Action Description Memorandum. Medical Isotope Production Program*. SNA-94-047, U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico.

U.S. Department of Energy (DOE). 1994f. *Radionuclide Air Emissions Annual Report for the Los Alamos National Laboratory*, Calendar Year 1993. U.S. Department of Energy, Los Alamos, New Mexico.

U.S. Department of Energy (DOE). 1995a. *Draft Waste Management Programmatic Environmental Impact Statement for Management Treatment, Storage and Disposal of Radioactive and Hazardous Waste, Volume I of IV*. DOE/EIS-0200-D, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1995b. *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement*. DOE/EIS-0203-F, U.S. Department of Energy, Office of Environmental Management, Idaho Falls Operations Office, Idaho Falls, Idaho.

U.S. Department of Energy (DOE). 1995c. *Public Scoping Hearings Transcripts on Production at LANL*. U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1995d. "Startup and Restart of Nuclear Facilities." DOE Order 0425.1, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1995e. "Packaging and Transportation Safety." DOE Order 0460.2, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1995f. *Proposed Medical Isotope Production Project Scoping Meeting*. Afternoon Session, July 24, 1995, Idaho Falls, Idaho.

U.S. Department of Energy (DOE). 1995g. *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement, Volume 1, Appendix E*. DOE/EIS-0203-F, U.S. Department of Energy, Office of Environmental Management, Idaho Falls Operations Office, Idaho Falls, Idaho.

U.S. Department of Energy (DOE). 1995h. *Draft Environmental Assessment of the Environmental Restoration Project at Sandia National Laboratories/New Mexico*. DOE/EA-1140, U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico.

U.S. Department of Energy (DOE). 1995i. *Dual Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement*. DOE/EIS-0228, U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico.

U.S. Department of Energy (DOE). 1995j. *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement, Volume 2, Part A*. DOE/EIS-0203-F, U.S. Department of Energy, Office of Environmental Management, Idaho Falls Operations Office, Idaho Falls, Idaho.

U.S. Department of Energy (DOE). 1995k. *Estimating the Cold War Mortgage; The 1995 Baseline Environmental Management Report, Volume 1 and Volume 2: Site Summaries*. DOE/EM-0232, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1995l. *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement, Volume I, Appendix F*. DOE/EIS-0203-F, U.S. Department of Energy, Office of Environmental Management, Idaho Falls Operations Office, Idaho Falls, Idaho.

U.S. Department of Energy (DOE). 1995m. *Lease of Parcel ED-1 of the Oak Ridge Reservation by the East Tennessee Economic Council*. Draft Environmental Assessment. DOE/EA-1113, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tennessee.

U.S. Department of Energy (DOE). 1995n. *DOE Related Employment: Oak Ridge Field Office Payroll Totals by Congressional Districts*. Data for December 31, 1994 to January 31, 1995. U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tennessee.

U.S. Department of Energy (DOE). 1995o. *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement, Volume I, Appendix B*. DOE/EIS-0203-F, U.S. Department of Energy, Office of Environmental Management, Idaho Falls Operations Office, Idaho Falls, Idaho.

U.S. Department of Energy (DOE). 1995p. *Air Emissions Annual Report [ES/ESH-56] [under Subpart H, 40 CFR 61.94] CY 1994*. U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tennessee.

U.S. Department of Energy (DOE). 1995q. *1994 Idaho National Engineering Laboratory (INEL) National Emission Standards for Hazardous Air Pollutants (NESHAP) Radionuclides Annual Report*. U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho.

U.S. Department of Energy (DOE). 1995r. *Disposition of Highly Enriched Uranium Obtained from the Republic of Kazakhstan*. DOE/EA-1063, Washington, D.C.

U.S. Department of Interior (DOI). 1990. *Endangered and Threatened Wildlife and Plants; Review of Plant Taxa for Listing as Endangered or Threatened Species; Notice of Review*, Federal Register, Volume 55, No. 35, Part IV, 50 CFR Part 17, U.S. Department of Interior, February 21.

U.S. Department of Interior (DOI). 1991. *Endangered and Threatened Wildlife and Plants; Animal Candidate Review for Listing as Endangered or Threatened Species, Proposed Rule*, Federal Register. Volume 56, No. 225, Part VIII, 50 CFR Part 17, U.S. Department of Interior, Washington D.C.

U.S. Department of Interior (DOI). 1992. *Endangered and Threatened Wildlife and Plants*. 50 CFR Parts 17.11 and 17.12, U.S. Department of Interior, Washington, D.C.

U.S. Department of Interior (DOI). 1995a. U.S. Department of Interior Fish and Wildlife Service letter, January 23, 1995 (USFWS 1995). U.S. Department of Interior, Washington, D.C.

U.S. Department of Interior (DOI). 1995b. U.S. Department of Interior Fish and Wildlife Service letter, June 19, 1995 (USFWS 1995). U.S. Department of Interior, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1988. "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion." *Federal Guidance Report No. 11*, EPA-500/1-88-020, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1989a. *National Emissions Standards for Hazardous Air Pollutants; Radionuclides; Final Rule and Notice of Reconsideration*. U.S. Environmental Protection Agency, Code of Federal Regulations, Title 40, Part 61, 54 F.R. 240,5164-51715 (December 15, 1989). U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1989b. *National Primary Drinking Water Regulations*. U.S. Environmental Protection Agency, Code of Federal Regulations, Title 40, Part 141 (1989). U.S. Environmental Protection Agency, Washington, D.C.

U.S. Food and Drug Administration (FDA). 1995. *Annual Registration of Drug Establishment, Registration for the Year 1995*. U.S. Food and Drug Administration, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1977. *Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes*. NUREG-0170, U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1984. *Environmental Impact Appraisal. Union Carbide Corporation Medical Products Division, Tuxedo, New York. Related to License Renewal of Special Nuclear Materials License No. SNM-639*. Docket No. 70-687, Division of Fuel Cycle and Material Safety, U.S. Nuclear Regulatory Commission, Washington, D.C.

White, G. C. 1981. *Biotelemetry Studies on Elk*. LA-8529-NERP, Los Alamos National Laboratory, Los Alamos, New Mexico.

Wilmot, E. L. 1981. *Transportation Accident Scenarios for Commercial Spent Fuel*. SAND80-2124, Sandia National Laboratory, Albuquerque, New Mexico.

Wong I., K. Coppersmith, W. Silva, R. Youngs, T. Sawyer, M. Hemphill-Haley, C. Stark, P. Knuepfer, R. Castro, F. Makdisi, D. Wells, S. Chiou, R. Bruhn, and W. Daning. 1992. *Earthquake Ground Motion Evaluations for the Proposed New Production Reactor at the Idaho National Engineering Laboratory Volume I: Deterministic evaluation*. EGG-GEO-10304, Office of New Production Reactors, Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho.

Wong, I., K. Kelson, S. Olig, T. Kolbe, M. Hemphill-Haley, J. Bott, R. Green, H. Kanakarai, J. Sawyer, W. Silva, C. Stark, C. Haraden, C. Fenton, J. Unruh, J. Gardner, S. Reneau, and L. House. 1995. *Seismic Hazards Evaluation of the Los Alamos National Laboratory*. Final Report. Woodward-Clyde Federal Services, Oakland, California.

Appendix A

Molybdenum-99 Production and Separation Performance Characteristics

Appendix A

Molybdenum-99 Production and Separation Performance Characteristics

Performance Characteristics and Assumptions

The approach to determine if a facility would be acceptable for molybdenum-99 (Mo-99) generation is based on the ability of that facility to irradiate targets, chemically process targets, verify product purity, package the product, ship the product, and manage the waste produced from the process. Several parameters are not independent, and many are fostered from one primary parameter, which is the integrated target power required for 100% production of the domestic demand.

Approximately 3000 6-day curies per week must reach the pharmaceutical houses for distribution to the regional radiopharmaceutical distributors. They, in turn, distribute to the clinics and hospitals using a *just-in-time* distribution method. A 6-day curie (which is an unusual unit of measure) is defined as the amount of material that will result in 1 curie of material remaining after a 6-day (144-h) decay. Therefore, approximately 13,600 actual curies must reach the pharmaceutical houses each week to achieve the 3000 6-day curie requirement.

To determine the number of curies removed from the reactor, an assessment must be made regarding the time required to move material from the reactor and deliver the extracted product to the pharmaceutical house. After a target is removed from the reactor, it must cool radioactively to reduce the total radiation. Time is required to transport the target to the processing facility, to remove the target from the transporter shield into the processing hot cell, to process the target material, to package the processed material, and to ship the material to the city of destination(s). Time is also required to transport the material from the airport to the pharmaceutical company.

Assuming 1 h to remove the target, 6 h to radioactively cool, 2 h to load in the transport assembly and transport to the hot cells, 1 h to unload from the transport cask to the hot cell, 8 h to process, 1 h to sample for purity and package, 1 h for ground transportation, 8 h for air transport, and another hour for ground transportation at the pharmaceutical city, a total of 29 h is achieved. No contingency is assumed in this estimate.

The chemical separation process is not perfect. Discussions with various chemists at Battelle and with John Brasier of Idaho National Engineering Laboratory (INEL), who has performed the process, indicate the separation process should produce approximately a 95% yield. This yield would increase the integrated target power required to produce 100% of the U.S. demand.

Very simplistic calculations can show that if a 95% process yield is assumed and the time described is 24 h, the integrated target power must be 460 kW. The same yield assumption and 36 h yield 521 kW, and 30 h requires 490 kW of integrated target power. A total of 30 h and 490 kW of integrated target power is considered the reasonable time and power to be assumed in assessing the various facilities.

The power in a single target is not very flux dependent, in that increased uranium loading in the target can adjust the target power to the level desired. The increased loading could probably be performed, within certain bounding values, during electroplating. The limiting consideration for single target power is the ability of the facility to thermally cool the target. The heat flux from a single target is approximately 2.19 watts/cm² per kW of target power. For comparison a commercial BWR pin, at the maximum licensed linear heat generation rate, is approximately 100 watts/cm².

The process waste generation, by volume, is a function of the number of targets required to produce the full U.S. demand. If a given facility can run at higher target powers, the volume of process waste generated decreases. However, target power also impacts hot cell operation. Hot cells are licensed to handle certain curie contents, usually at a specified level of emitted gamma energy. Some cells could process several high powered targets at once. Certain other cells may be capable of processing only a single target, and may require additional cooling time in excess of 6 h to be capable of processing a single high power target.

A rough calculation based on American National Standards Institute (ANSI) decay heat standards, and collaborated by ORIGEN calculations, indicate the following approximate relationship. For a target after a 6-day irradiation, the total activity, in curies, per kW of target power versus cooling time is given by the following approximating polynomial: $KCi/KW = 1.141 - 0.0905(t) + 0.00375(t^2)$ where t is in hours. This calculation yields the following approximate values: 4 h-0.84KCi/KW, 6 h-0.73KCi/KW, 8 h-0.66KCi/KW, 10 h-0.61KCi/KW, and 12 h-0.595KCi/KW. For example, a 20 kW target allowed to cool for 8 h contains approximately 13,200 total curies. This total impacts the number of targets that can be processed in a single batch, and must be assessed on a site-by-site basis.

Reactor fuel utilization must be considered. The fuel burned to produce the neutrons required for target irradiation is basically encapsulated radioactive material. Nuclear fuel has the fission products contained within the cladding, and is special in radioactive material handling. It is advantageous to burn less fuel to produce the neutrons required for irradiation of the targets.

The site's ability to handle waste streams must be considered. The additional impact that production of Mo-99 would have on the site waste handling process must be considered. Shipping of waste must also be considered. It is advantageous to dispose of waste at the same site where the waste is produced, precluding the necessity of waste shipping.

Irradiation time has a strong effect on specific activity. All of the molybdenum isotopes from Mo-95 to Mo-100 are produced from fission. Because of the removal coefficient of Mo-99, effectively a 4-day exponential lifetime, it equilibrates rapidly. The other molybdenum isotopes produced from fission continue to build, making the Mo-99 curie content per gram of molybdenum material decrease with increased irradiation times. Long irradiation times driven by schedule needs are clearly disadvantageous.

Part, or all, of the above issues were considered when assessing the viability of a particular option. These issues were not pursued in great depth. Detailed technical considerations of the items were not performed as a function of the selection criteria, but rather a qualitative assessment for reasonability was performed.

Cintichem Process Description

Target Fabrication. Target elements are manufactured by electroplating the inner wall of a stainless steel tube with 20 g of enriched uranium oxide. The target cylinder is then evacuated, back-filled with helium and the end fittings are welded onto the target body.

Target Irradiation. Targets are placed in the reactor's central core region (or appropriate flux trap) and irradiated around the clock for approximately 7 days. Targets are loaded and removed from the core on a staggered schedule to assure daily (or frequent periodic) batches of isotopes for processing. They are then transferred to a hot cell facility for chemical separation.

Chemical Separation and Purification. The chemical recovery of Mo-99 from the targets proceeds only after a minimum decay period of approximately 6 h. The steps in the process include the dissolution of the uranium coating, the separation of the molybdenum from other fission products, and the purification of the molybdenum.

Dissolution of the Uranium Coating. A manifold and cold trap are installed to recover the noble gases and iodine from the target fill gas. The manifold and cold trap are then removed and an acid solution is added to dissolve the uranium coating. The targets are rotated and heated to aid dissolution. At this point, the manifold, cold trap, and an iodine trap are reinstalled to recover the iodine and remaining gases. These items are then sent to xenon and iodine recovery cells. The liquid remaining (the target solution) is drained into a container. The target solution then contains approximately 92 g of fission products, target fuel, and acid solution.

Separation of the Molybdenum from Other Fission Products. A series of steps is conducted to place molybdenum in the form of solid molybdenum oxide. First, rinse water is added to the target and drained into the container of target solution. The target is then placed into a low activity disposal container.

A series of chemicals is added to the target solution. These chemicals are listed in the order of addition: 4 g of iodine carrier, 0.51 g nitric acid and 0.01 g silver nitrate (mixed), 1 g hydrochloric acid, 1 g molybdenum carrier, 1 g potassium permanganate solution, 1 g rhodium carrier solution 0.7 g, ruthenium carrier solution, and 20 g of benzoin alpha oxime solution. The target solution is agitated after the addition of each chemical. The total volume of the target solution and molybdenum precipitant at the end of this process is 147 g.

The target solution is then poured through a molybdenum precipitant into another container. The empty target solution container is cleaned with 20 g of sulfuric acid cleaning solution, which is then again poured through the molybdenum precipitant, and into the container with the target solution. This procedure is repeated three times and the empty target solution container is sent to a low activity disposal container.

Molybdenum precipitant is rinsed with 10 g sulfuric acid cleaning solution and drained into an acid wash container. The solution in the acid wash container is poured into the molybdenum precipitant and then drained back into the same container. This acid wash container is then sent to low activity disposal.

Purification of Molybdenum. Molybdenum precipitant is injected with 10 g of molybdenum suspension solution and drained into a new container. This solution is poured through an ion resin exchange filter and back into the new container. The ion resin exchange filter is sent to low activity disposal containers. The container with the molybdenum is then ready to send to the pharmaceutical shipment cask.

Appendix B

Analysis of Transportation Impacts

Appendix B

Analysis of Transportation Impacts

B.1 Transportation

This appendix evaluates the transportation impacts associated with the production of medical isotopes. The alternatives evaluated have been described in Section 3. Potential transportation impacts could include external radiation exposures during routine transport and internal and external exposures due to vehicular accidents that result in a release of radioactive materials. Nonradiological impacts from routine and vehicular accidents are also addressed. The nonradiological routine impacts are due to pollutants emitted by the transport vehicles and the vehicular accident impacts are due to traumatic fatalities.

For each alternative, the routine and accidental radiological and nonradiological impacts associated with transporting unirradiated targets from the target fabrication site to the reactor; transporting irradiated targets from the reactor to a processing facility for separation; and transporting the separated medical isotope from the processing facility to the pharmaceutical distributor were evaluated. Impacts associated with transporting the wastes generated during processing were also addressed. The impacts of transporting spent nuclear fuel are not addressed, because each of the reactor facilities has available spent fuel storage capacity (see Section 5.14). Therefore, no near term impacts are associated with the transport of spent nuclear fuel from the reactor facilities to an interim or permanent offsite storage facility. The environmental impacts of managing DOE's spent nuclear fuel inventory are addressed in Massey and Coats (1995).

B.1.1 Methods and Assumptions

The following sections describe the methods and assumptions used to evaluate potential impacts of each of the medical isotope alternatives. The analysis focuses on the activities associated with transportation of the unirradiated and irradiated targets, medical isotopes, and process waste.

B.1.1.1 Shipping Scenarios

A total of five transportation scenario alternatives are addressed in this evaluation. The alternatives, based on handling or operation location, are shown in Table B-1. It was assumed that all overland transportation would be performed by truck. For example, unirradiated targets would be transported from the fabrication facility to the irradiation facility by truck and final product would be transported to and from the airport by truck. For all alternatives, it was assumed that maximums of 52 target shipments/yr and 1140 purified medical isotopes shipments/yr would be required to meet the demand, (that is, 100% of the U.S. market). Of the 1140 shipments, 1035 shipments would contain 3 packages each of Mo-99,

Table B-1. Transport Scenarios Based on Handling or Operation Location

Target Fabrication	Target Irradiation	Separations	Airport	Final Destination Airport (Distributor)
LANL	LANL	LANL	Albuquerque International Airport	Boston, MA (DuPont-Merck)
				Chicago, IL (Amersham Medipysics)
				St. Louis, MO (Mallinckrodt Medical)
				Ottawa, Canada (Nordion)
LANL/SNL/NM	SNL/NM	SNL/NM	Albuquerque International Airport	Same as Above
ORNL	ORNL	ORNL	McGhee Tyson Airport	Same as Above
INEL	INEL	INEL	Idaho Falls Airport	Same as Above
LANL - Los Alamos National Laboratory SNL/NM - Sandia National Laboratories/New Mexico ORNL - Oak Ridge National Laboratory INEL - Idaho National Engineering Laboratory				

xenon-133, and iodine-131, and 105 shipments would contain 3 packages of iodine-125. It was also assumed, based on the total number of targets shipped and that a representative waste cask would contain processing waste from 14 irradiated targets, a maximum of 90 waste shipments would be made per year.

The following paragraphs describe each of the scenarios based on target fabrication, irradiation and separations location, and final destination. Most flights would require connecting flights between the original airport and the destination airport. The transportation scenarios from the final destination (airport) to the distributor are common to all alternatives and are discussed only in the initial alternative.

Los Alamos Target Fabrication, Irradiation, Separations, and Shipments from Albuquerque International Airport. This scenario assumes the targets would be fabricated at LANL in the Chemistry and Metallurgy Research Facility located in TA-3 and transported approximately 6.5 km (4 mi), via truck on existing site roads, to the Omega West Reactor located in TA-2. Following irradiation in the Omega

West Reactor, the targets would be transported via truck to the Chemistry and Metallurgy Research Facility, using the same route, for separation and purification of the medical isotopes. Waste generated during separation is assumed to be low-level solid waste, and would be transported approximately 8 km (5 mi) to an onsite disposal facility in TA-54.

The purified medical isotopes would be packaged and transported by truck to Albuquerque International Airport for transport to DuPont-Merck, Amersham Medipysics, Mallinckrodt Medical, or Nordion. The total shipping distance from TA-3 to Albuquerque International Airport is approximately 153 km (95 mi). Of the total distance, 18 km (12 mi) are on existing site roads, and the remaining 135 km (83 mi) are on public roadways.

For shipments to DuPont-Merck, the nearest commercial airport is Logan International in Boston, Massachusetts. The total flight distance from Albuquerque International Airport to Logan International is approximately 3200 km (1970 mi). The package containing the purified medical isotopes would be transferred to a truck and transported 35 km (22 mi) to the DuPont-Merck facility located in Billerica, Massachusetts.

For shipments to Amersham Medipysics, the nearest commercial airport is O'Hare in Chicago, Illinois. The total flight distance from Albuquerque International Airport to O'Hare is approximately 1800 km (1120 mi). The package containing the purified medical isotopes would be transferred to a truck and transported 32 km (20 mi) to the Amersham Medipysics facility located in Arlington Heights, Illinois.

For shipments to Mallinckrodt Medical, the nearest commercial airport is St. Louis International in St. Louis, Missouri. From Albuquerque International Airport to St. Louis, the total flight distance is approximately 2200 km (1350 mi). The package containing the purified medical isotopes would be transferred to a truck and transported 13 km (8 mi) to the Mallinckrodt facility located in Hazelwood, Missouri.

For shipments to Nordion, the nearest commercial airport is Ottawa, Canada. It was assumed that shipments to Nordion would be from Albuquerque International Airport to a distribution hub and at the hub the isotope packages would be transferred to a plane departing for Ottawa, Canada. The estimated total flight distance is approximately 3000 km (1872 mi). At the Ottawa airport, the package would be transferred to a truck and transported to Nordion. The air transport portion of this alternative is similar (approximately the same distance) to the DuPont-Merck alternative and was not specifically evaluated. That is, the expected impacts would be similar to the impacts associated with delivery of the isotopes to Logan International.

Los Alamos Target Fabrication, Sandia National Laboratories Irradiation, Separations, and Shipments from Albuquerque International Airport. This scenario assumes the targets would be fabricated at LANL in the Chemistry and Metallurgy Research Facility located in TA-3 and transported approximately 176 km (110 mi), via truck on existing LANL and Sandia National Laboratories/New Mexico (SNL/NM) site roads (28 km [17 mi]) and public roads (148 km [92 mi]), to the SNL/NM Annular Core Research Reactor. Following irradiation in the Annular Core Research Reactor, the irradiated targets

would be transferred to the adjacent SNL/NM Hot Cell Facility, for separation and purification of the medical isotopes. The Annular Core Research Reactor and the Hot Cell Facility are located in Technical Area V. Waste generated during separation is assumed to be low-level solid waste and would be transported approximately 1099 km (683 mi) to the Nevada Test Site for disposition.

The purified medical isotopes would be packaged and transported by truck to Albuquerque International Airport for transport to DuPont-Merck, Amersham Medipysics, or Mallinckrodt Medical. The total shipping distance from Technical Area V to Albuquerque International Airport is approximately 17 km (11 mi). Of the total distance, 9 km (6 mi) are on existing site roads, and the remaining 8 km (5 mi) are on public roadways.

For shipments to DuPont-Merck, Amersham Medipysics, Mallinckrodt Medical, and Nordion the air transportation routes and final destinations (airports) would be the same as discussed previously for LANL. Transportation of the package containing the purified medical isotopes to the distributors from the destination airport would also be the same as for shipments from LANL.

Sandia National Laboratories Target Fabrication, Irradiation, Separations, and Shipments from Albuquerque International Airport. This scenario assumes the targets would be fabricated at the SNL/NM in the Hot Cell Facility located in Technical Area V and transferred to the Annular Core Research Reactor, also located in Technical Area V. Following irradiation in the Annular Core Research Reactor, the irradiated targets would be returned to the adjacent Hot Cell Facility, for separation and purification of the medical isotopes. Waste generated during separation is assumed to be low-level solid waste and would be transported approximately 1099 km (683 mi) to the Nevada Test Site for disposition.

The purified medical isotopes would be packaged and transported by truck to Albuquerque International Airport for transport to DuPont-Merck, Amersham Medipysics, or Mallinckrodt Medical. The total shipping distance from Technical Area V to Albuquerque International Airport is approximately 17 km (11 mi). Of the total distance, 9 km (6 mi) are on existing site roads, and the remaining 8 km (5 mi) are on public roadways.

For shipments to DuPont-Merck, Amersham Medipysics, Mallinckrodt Medical, and Nordion, the air transportation routes and final destinations (airports) would be the same as discussed previously for LANL. Transportation of the package containing the purified medical isotopes to the distributors from the destination airport also would be the same as for shipments from LANL.

Oak Ridge National Laboratory Target Fabrication, Irradiation, Separations, and Shipments from McGhee Tyson Airport. This scenario assumes the targets would be fabricated at the ORNL in the Radioisotope Development Laboratory and transferred to the Oak Ridge Research Reactor. Following irradiation in the Oak Ridge Research Reactor, the irradiated targets would be returned to the Radioisotope Development Laboratory, for separations and purification of the medical isotopes. Waste generated during separation is assumed to be low-level solid waste and would be transported approximately 3300 km (2050 mi) to the Nevada Test Site for disposal.

The purified medical isotopes would be packaged and transported by truck to McGhee Tyson Airport for transport. The total shipping distance from the Radioisotope Development Laboratory to McGhee Tyson Airport is approximately 40 km (25 mi). Of the total distance, 11 km (7 mi) are on existing site roads, and the remaining 29 km (18 mi) are on public roadways.

For shipments to DuPont-Merck, Amersham Medipysics, Nordion, and Mallinckrodt Medical, the final destinations (airports) would be the same as discussed previously for LANL. The total flight distances are shown in Table B-2. Transportation of the package containing the purified medical isotopes from the airport to the distributors also would be the same as for shipments from LANL.

For shipments to Nordion, the nearest commercial airport is Ottawa, Canada. It was assumed that shipments to Nordion would be from McGhee Tyson Airport to a distribution hub and at the distribution hub the isotope packages would be transferred to a plane departing for Ottawa, Canada. The total flight distance is approximately 1380 km (858 mi). At the airport, the package would be transferred to a truck and transported to Nordion. The air transport portion of this alternative is similar (approximately the same distance) to the DuPont-Merck alternative and was not specifically evaluated. That is, the expected impacts would be similar to the impacts associated with delivery of the isotopes to Logan International.

Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, and Shipments from Idaho Falls Airport. This scenario assumes the targets would be fabricated at the INEL in a hot cell facility located in the Test Area North. The unirradiated targets would be shipped by truck on existing INEL site roads from the Test Area North, approximately 53 km (33 mi) to the Power Burst Facility. Following irradiation in the reactor, the targets would be transported via truck, to the Test Area North, for separation and purification of the medical isotopes, using the same route. Waste generated during separation is assumed to be low-level solid waste and would be transported approximately 44 km (27 mi) to a disposal site west of the Idaho Chemical Processing Plant.

The purified medical isotopes would be packaged and transported by truck to Idaho Falls Airport for transport to DuPont-Merck, Amersham Medipysics, or Mallinckrodt Medical. The total shipping distance from the Test Area North to Idaho Falls Airport is approximately 120 km (75 mi). Of the total distance, 40 km (25 mi) are on existing site roads, and the remaining 80 km (50 mi) are on public roadways.

For shipments to DuPont-Merck, Amersham Medipysics, Nordion, and Mallinckrodt Medical, the final destinations (airports) would be the same as discussed in previously for LANL. The total flight distances are shown in Table B-2. Transportation of the package containing the purified medical isotopes from the airport to the distributors also would be the same as for shipments from LANL.

For shipments to Nordion, the nearest commercial airport is Ottawa, Canada. It was assumed that shipments to Nordion would be from Idaho Falls Airport to a distribution hub and at the distribution hub the isotope packages would be transferred to a plane departing for Ottawa, Canada. The total flight distance is approximately 3350 km (2080 mi). At the airport, the package would be transferred to a truck and transported to Nordion. The air transport portion of this alternative is similar (approximately the same distance) to the DuPont-Merck alternative and was not specifically evaluated. That is, the expected impacts would be similar to the impacts associated with delivery of the isotopes to Logan International.

Table B-2. Summary of Transportation Routing Information

Option/Material Transported		Shipments per year	Shipment Description (km one-way) ^(a)		Population Densities (people/km ²)				
Transportation Route			Onsite	Offsite	Onsite		Offsite		
Origin	Destination				Rural	Suburban	Rural	Suburban	Urban
Target fabrication, irradiation, separations, and waste handling at LANL									
Unirradiated Targets									
CMR Facility	Omega West Reactor	52	6.5	0	5	360	Not Applicable		
Irradiated Targets									
Omega West Reactor	CMR Facility	52	6.5	0	5	360	Not Applicable		
Low-Level Waste									
CMR Facility	Technical Area 54 ^(b)	90	8	0	5	360	Not Applicable		
Separated Medical Isotope									
CMR Facility	Albuquerque Int Airport	1520	18	135	5	360	9.2	385.1	2227.7
Albuquerque Int Airport	Boston, MA ^(c)	380		3200	See Table B-4				
Boston, MA	DuPont-Merck	380		56	Not Applicable		14.5	478.9	2563.5
Albuquerque Int Airport	Chicago, IL	380		1800	See Table B-4				
Chicago, IL	Amersham Medipysics	380		13	Not Applicable		7.8	670.3	2829.0
Albuquerque Int Airport	St. Louis, MO	380		2200	See Table B-4				
St. Louis, MO	Mallinckrodt	380		8	Not Applicable		2.3	778.1	2611.2
Target fabrication at LANL or SNL, irradiation, and separations at SNL, and waste handling at the Nevada Test Site									
Unirradiated Targets									
LANL-CMR Facility	ACR Reactor	52	28	148	5	360	9.2	385.1	2227.7
SNL-Hot Cell Facility	ACR Reactor	52	0	0	5	360	Not Applicable		
Irradiated Targets									
ACR Reactor	Hot Cell Facility	52	0	0	5	360	Not Applicable		
Low-level Waste									
Hot Cell Facility	Nevada Test Site ^(b)	90	9	1099	5	360	3.3	475.9	2295.2
Separated Medical Isotope (Shipments from Albuquerque Int Airport to distributors as above)									
Hot Cell Facility	Albuquerque Int Airport	1520	9	8.5	5	360	28.0	546.3	2333.1

Table B-2. (contd)

Option/Material Transported		Shipments per year	Shipment Description (km one-way) ^(a)		Population Densities (people/km ²)				
Transportation Route			Onsite	Offsite	Onsite		Offsite		
Origin	Destination				Rural	Suburban	Rural	Suburban	Urban
Target fabrication, irradiation, and separations at ORNL, and waste handling at Nevada Test Site									
Unirradiated Targets									
Radioisotope Development Lab	Reactor	52	0	0	5	360	Not Applicable		
Irradiated Targets									
Reactor	Radioisotope Development Lab	52	0	0	5	360	Not Applicable		
Low-level Waste									
Radioisotope Development Lab	Nevada Test Site ^(b)	90	11	3300	5	360	6.5	346.7	2214.7
Separated Medical Isotope (Shipments from Destination Airports to distributors as above)									
Radioisotope Development Lab	McGhee Tyson Airport	1520	11	29	5	360	6.6	412.1	1764.7
McGhee Tyson Airport	Boston, MA ^(c)	380	Not Applicable	1340	See Table B-4				
McGhee Tyson Airport	Chicago, IL	380	Not Applicable	750					
McGhee Tyson Airport	St. Louis, MO	380	Not Applicable	650					
Separated Medical Isotope (Shipments from Destination Airports to distributors as above)									
Target fabrication, irradiation, separations, and waste handling at INEL									
Unirradiated Targets									
Test Area North Facility	Power Burst Facility Reactor	52	53	0	5	360	Not Applicable		
Irradiated Targets									
Power Burst Facility Reactor	Test Area North Facility	52	53	0	5	360	Not Applicable		
Low-level Waste									
Test Area North Facility	ICPP ^(b)	90	44	0	5	360	Not Applicable		
Separated Medical Isotope (Shipments from Destination Airports to distributors as above)									
Test Area North Facility	Idaho Falls Airport	1520	80	40	5	360	1.1	522.1	1986.1
Idaho Falls Airport	Boston, MA	380	Not Applicable	3320	See Table B-4				
Idaho Falls Airport	Chicago, IL	380	Not Applicable	1990					
Idaho Falls Airport	St. Louis, Mo	380	Not Applicable	1890					
Separated Medical Isotope (Shipments from Destination Airports to distributors as above)									

(a) Zero onsite distance implies facilities are adjacent.

(b) Assuming 52-target shipments/yr, 24 targets/shipment, and waste from 14 targets/waste cask.

(c) Transportation impacts for shipments and the number of shipments to Nordion are similar or bounded by the analyses.

B.1.1.2 Shipping System Descriptions

Currently, four potential reactors and processing facilities are identified as potential alternatives for the production of the medical isotopes. Each of the reactor facilities would have specific requirements regarding the target design. Similarly each reactor or hot cell facility would also have specific cask handling capabilities. Therefore, a representative target design and shipping package configuration, based on LANL (1993e), was selected for evaluation.

The following sections provide descriptions of the representative shipping cask for unirradiated target shipments, irradiated target shipments, and both overland and air medical isotopes shipments. For all but one of the options (target fabrication at LANL and irradiation and separations at SNL), all target transportation would be onsite. However, all shipments would be made by truck and would comply with the appropriate DOT requirements contained in 10 CFR 71 (Type B container) and 49 CFR 173 (Type A container). All air shipments would comply with the requirements contained in 49 CFR 175.

Representative Target Truck Shipping Container and Cask. The target container and shipping cask described in LANL (1993e) would be used for transporting irradiated targets. This target transfer container is approximately 10 cm (4 in.) in diameter and 76 cm (30 in.) deep and surrounded by a 16 cm (6 in.) thick shield of stainless steel clad depleted uranium. A target transfer container can hold up to four irradiated targets, which would be shipped in Type B casks.

The number of unirradiated or irradiated targets to be shipped at one time would be a maximum of 24, that is, 6 target transfer containers packaged in a Type A container or 6 Type B casks containing 4 targets each or 2 casks containing 12 targets. Based on a common target design (up to 20 grams of 93% highly enriched uranium [HEU] per target) and cask capacity (24 targets per cask), the limits contained in Part 71.22 of 10 Code of Federal Regulations, General License: Type A package, Fissile Class III shipment (500 grams per shipment) would not be exceeded.

Representative Separated Medical Isotopes Truck and Air Shipping Cask. The separated medical isotopes would be transported in a Type B shipping cask by truck to the departure airport and from the destination airport to the medical isotope distributors, identified in B.1.1.1. It was assumed a representative Type B cask similar to CI-20WC-2 model would be used. The cask would be certified for air transport using commercial passenger or cargo flights. Based on the cask surface dose rates, additional shielding would be required for passenger flight shipments to meet regulatory requirements. This cask may contain up to 1000 Ci of Mo-99/Tc-99 in normal form as solids or liquid or up to 200 Ci of I-131.

Similar to the CI-20WC-2, the representative casks are depleted uranium shielded casks that are steel encased with wooden outer protective jackets and an inner steel containment vessel. The outer protective jacket (wood) is 24-1/4 x 22 x 28-3/4 in. and the depleted uranium shield is 2 in. thick with a 3.1 x 6 in. cylindrical cavity. The inner containment vessel, constructed of stainless steel, is a 2.73 in OD X 5.56 in. long. The gross weight of the package is about 400 lbs.

The CI-20WC-2 cask is not currently certified for international shipments. However, often cask designs suitable for transport of Mo-99 product are certified for international transport. The capacities and shielding of the internationally-certified casks are similar to those of the CI-20WC-2 cask and would not have a large effect on the number of shipments and their dose rates. Certification of the CI-20WC-2 cask for international transport is an option, if for some reason the internationally-certified casks are unavailable.

Representative Low-Level Waste Truck Shipping Cask. It is assumed that a B-3 Type B package would be used to transport waste packages on onsite and public roadways. This package is a steel cylindrical container with a lead shield (a minimum of 6 in.), a bottom drain assembly, and a gasketed and bolted lid. This package is suitable for transporting low-level solid wastes. The maximum weight of the loaded package is 30,000 lbs.

B.1.1.3 Transportation Route Information

The transportation route information used in this analysis is shown in Table B-2. The information shown in Table B-2 includes the shipping distances and population density data. These data were developed using the HIGHWAY (Joy and Johnson 1992) computer code for truck shipments, or estimated using site maps, and are used to calculate transportation impacts. The population density data for onsite shipments were developed using site maps and use suburban population densities to represent occupied facilities and rural population densities for all other areas adjacent to the transport route. These data are summarized in Table B-2 for each transport segment described in Section B.1.1.1.

B.1.1.4 Description of Methods Used to Estimate Consequences

This section describes the methods used to estimate consequences of normal and accidental exposure of individuals or populations to radioactive materials. The RADTRAN 4 (Neuhauser and Kanipe 1992) computer code was used to calculate the transportation impacts. The GENII software package (Napier et al. 1988) was used to estimate the radiological dose to maximally exposed individuals (MEI).

The output from computer codes, as total effective dose equivalent (TEDE) to the affected receptors, was then used to express the consequences in terms of potential latent cancer fatalities. Recommendations of the International Commission on Radiological Protection (ICRP 1991) for low dose rate radiological exposures were used to convert dose as total effective dose equivalent to latent cancer fatalities. The conversion factor applied to adult worker populations was 4×10^{-4} latent cancer fatalities/rem TEDE, and that for the general population was 5×10^{-4} latent cancer fatalities/rem TEDE. The general population was assumed to have a higher rate of cancer induction for a given radiation dose than the healthy adult worker population because of the presence of more sensitive individuals (such as, children) in the general population.

RADTRAN 4 Description. The RADTRAN 4 computer code (Neuhauser and Kanipe 1992) was used to perform the analyses of the radiological impacts of routine transport and the integrated population

risks of accidents during transport. RADTRAN was developed by SNL/NM to calculate the risks associated with the transportation of radioactive materials. The original code was written by SNL/NM in 1977 in association with the preparation of NUREG-0170 (NRC 1977). The code has since been refined and expanded and is currently maintained by SNL/NM under contract from DOE. RADTRAN 4 is an update of the RADTRAN 3 (Madsen et al. 1986) and RADTRAN 2 (Taylor and Daniel 1982; Madsen et al. 1983) computer codes.

The RADTRAN 4 computer code is organized into the seven models listed as follows (Neuhauser and Kanipe 1992):

- material model
- transportation model
- population distribution model
- health effects model
- accident severity and package release model
- meteorological dispersion model
- economic model.

The code uses the first three models to calculate the potential population dose due to normal, incident-free transportation and the first six models to calculate the risk to the population from user-defined accident scenarios. The economic model is not used in this study. Population densities for each route were developed using Highway 5.0 (Joy and Johnson 1992) as inputs to RADTRAN 4. These data, which include the population densities and travel distances (or fractions of the route) in rural, urban, and suburban areas, are presented in Table B-3.

Material Model. The material model defines the source as either a point source or as a line source. For exposure distances less than twice the package dimension, the source was conservatively assumed to be a line source. For all other cases, the source was modeled as a point source that emits radiation equally in all directions.

The material model also contains a library of 59 isotopes, each of which has 11 defining parameters used in the calculation of dose. The user can add isotopes not in the RADTRAN library by creating a data table file consisting of 11 parameters in the input.

Transportation Model. The transportation model allows the user to input descriptions of the transportation route. A transportation route may be divided into links or segments of the journey with information for each link on population density, mode of travel (for example, trailer truck or ship), accident rate, vehicle speed, road type, vehicle density, and link length. Alternatively, the transportation route can also be described by aggregate route data for rural, urban, and suburban areas. For this analysis, the aggregate route method was used for each potential origin-destination combination. The origin-destination combinations addressed in this analysis are discussed in Section B.1.1.1.

Health Effects Model. The health effects model in RADTRAN 4 is replaced by hand calculations. The health effects are determined by multiplying the population dose (person-rem) calculated by RADTRAN 4 by a conversion factor. The conversion factors relate population dose to latent cancer fatalities and total detriment from cancer fatalities, cancer incidence, and genetic effects. Only cancer fatalities

Table B-3. RADTRAN Input Parameters for Truck Shipments

Parameter	Unirradiated Target	Irradiated Target	Separated Isotope	Low-Level Waste
Dose rate 1 m from Vehicle/Package (mrem/h) ^(a)	1.4	10	Mo-99 4.4 I-131 0.6 I-125 0.6 Xe-133 0.14	10
Length of Package (m)	1.0	1.0	0.8	
Velocity (Km/h) ^(b)	56.4	56.4	56.4	56.4
Percentage of Travel Distance in Rural Population Zone - Onsite	60	60	60	60
Percentage of Travel Distance in Rural Population Zone - Offsite ^(c)	1 - 0 2 - 84.7 3 - 0 4 - 0 5 - 0	1 - 0 2 - 0 3 - 0 4 - 0 5 - 0	1 - 84.7 2 - 2.5 3 - 2.5 4 - 38.7 5 - 96.9	1 - 0 2 - 90.8 3 - 90.8 4 - 68.0 5 - 0
Percentage of Travel Distance in Suburban Population Zone - Onsite	40	40	40	40
Percentage of Travel Distance in Suburban Population Zone - Offsite ^(c)	1 - 0 2 - 13.9 3 - 0 4 - 0 5 - 0	1 - 0 2 - 0 3 - 0 4 - 0 5 - 0	1 - 13.9 2 - 49.3 3 - 49.3 4 - 59.9 5 - 1.4	1 - 0 2 - 6.8 3 - 6.8 4 - 31.2 5 - 0
Percentage of Travel Distance in Urban Population Zone - Offsite ^(c)	1 - 0 2 - 1.4 3 - 0 4 - 0 5 - 0	1 - 0 2 - 0 3 - 0 4 - 0 5 - 0	1 - 1.4 2 - 48.2 3 - 48.2 4 - 1.3 5 - 1.2	1 - 0 2 - 6.8 3 - 6.8 4 - 0.8 5 - 0
Number of Truck Crewmen	2	2	2	2
Distance from Source to Crew (m)	10.0	10.0	10.0	10.0
Stop Time per km (h/km) ^(b)	0.011	0.011	0.011	0.011
Persons Exposed While Stopped ^(b)	50	50	50	50
Average Exposure Distance While Stopped (m) ^(b)	20.0	20.0	20	20.0
Number of People per Vehicle on Link ^(b)	2	2	2	2
(a) Taken from NUREG-0170 (NRC 1977).				
(b) Default values from RADTRAN (Neuhauser and Kanipe 1992 and Madsen et al. 1983).				
(c) 1 -,2 -,3 -,4 -, and 5 - refer to alternatives discussed in Section B.1.1.1.				

were considered in this assessment. The conversion factors were taken from the ICRP Publication 60 (ICRP 1991) and amount to 4×10^{-4} latent cancer fatalities per person-rem for workers and 5×10^{-4} latent cancer fatalities/person-rem for the general public.

Accident Severity and Package Release. Model Accident analysis in RADTRAN 4 is performed using the accident severity and package release model. The user can define up to 20 severity categories for three population densities (urban, suburban, and rural), each increasing in magnitude. NUREG-0170 (NRC 1977) defines eight severity categories for spent fuel containers that are related to fire, puncture, crush, and immersion environments. Various other studies have also been performed for small packages (Clarke et al. 1976) and large packages (Dennis et al. 1978), which can also be used to generate severity categories. The accident scenarios are further defined by allowing the user to input release fractions, and aerosol and respirable fractions for each severity category. These fractions are also a function of the physical-chemical properties of the materials being transported.

Meteorological Dispersion Model. RADTRAN 4 allows the user the choice of two different methods for the modeling of the atmospheric transport of radionuclides after a potential accident. The user can either input Pasquill atmospheric stability category data or averaged time-integrated concentrations. In this analysis, the dispersion of radionuclides after a potential accident is modeled by the use of time-integrated concentration values in downwind areas compiled from national averages by SNL/NM for use in RADTRAN4.

Incident-Free Transport. The models previously described are used by RADTRAN 4 to determine dose from incident-free transportation or risk from potential accidents. The public and worker doses calculated by RADTRAN 4 for incident-free transportation are dependent upon the type of material being transported and a corresponding transportation index for the package or packages of each material type. The transportation index is defined in 49 CFR 173.403(bb) as the highest package dose rate in millirem per hour at a distance of 1 m from the external surface of the package. Dose consequences are also dependent upon the size of the package, which as indicated in the material model description will determine whether the package is modeled as a point source or line source for close-proximity exposures.

Potential Accident Analysis. The potential accident analysis performed in RADTRAN 4 calculates population doses for each accident severity category using six exposure pathway models. They include inhalation, resuspension, groundshine, cloudshine, ingestion, and direct exposure. This RADTRAN 4 analysis assumes that any contaminated area is either mitigated or public access controlled so the dose via the ingestion pathway equals zero. The consequences calculated for each severity category are multiplied by the appropriate probabilities for accidents in each category and summed to give a total point estimate of risk for a radiological accident. The parameters used to calculate the frequencies and consequences of transportation accidents are presented in Section B.1.3.

RADTRAN 4 Input Parameters for Truck Shipments. RADTRAN 4 input parameters for calculating routine population doses include route information (shipping distances, population densities, and

fractions of travel in rural, suburban, and urban areas), numbers of shipments, dose rate, material inventories, and parameters that define the population exposure characteristics. The route information and numbers of shipments are presented in Table B-2 and not repeated here. The remaining exposure parameters are described as follows.

RADTRAN 4 uses the dose rate at 1 m (referred to as the transportation index^(a)) in calculating dose to the public and worker. All of the irradiated target and waste shipments in this analysis were assumed to be at the regulatory maximum dose rate, equating to a transportation index (TI) value of about 10 mrem/h. Because cask designs and shielding materials have not changed significantly since 1977, the TI used for the separated isotopes have been taken from NUREG-0170 (NRC 1977) and are as follows; highly enriched uranium 1.4 mrem/h, Mo-99 4.4 mrem/h, I-131 and I-125 0.6 mrem/h, and Xe-133 0.14 mrem/h. However, it is likely that many of these shipments would have significantly smaller TI values.

Tables B-3 and B-4 list the input parameters that are used by RADTRAN 4 in the calculation of population dose for incident-free transportation. Many of the parameters are default values in the RADTRAN 4 code. Those that are not default values are identified and their sources are provided in footnotes to the tables.

The potential receptors include workers and the general public. Worker doses include those received by the truck crew.

Public doses include doses to persons on the highway, doses to persons who reside near the highway and doses to nearby individuals at intermediate stops. For all truck shipping modes, the doses to passengers were assumed to be zero as no passengers would be traveling with the shipments. In addition, no intermediate storage needs were assumed for the shipments, so the doses to in-transit storage personnel were set equal to zero.

Information needed to characterize the potential routes include the shipping distances, onsite and offsite population densities in rural, suburban, and urban areas along the routes, and fractions of total shipping distance that travel through rural, suburban, and urban areas. These data are presented in Tables B-2 and B-3.

RADTRAN 4 Routine Exposure Parameters for Air Shipments. Air transport of the casks from Albuquerque to the pharmaceutical suppliers is expected to be accomplished by commercial air-cargo transport. The shipping casks would be unloaded from their truck shipments at the origin airport (Albuquerque, New Mexico; Idaho Falls, Idaho; and Knoxville, Tennessee), loaded aboard the aircraft, and shipped to the destination airport (Chicago, Illinois; Boston, Massachusetts; and St. Louis, Missouri), where they would be picked up and transported by truck to the pharmaceutical suppliers. Each shipment

(a) Transport index: defined as the radiation dose rate in mrem/h at 1 m from package surface.

Table B-4. RADTRAN 4 Input Parameters for Passenger Air Shipments

Parameter	Value	Source
Population density, takeoff and landing	3861 people per km ²	NUREG-0170 (NRC 1977); represents high-density urban area
Population density, in-flight	719 people per km ²	NUREG-0170 (NRC 1977); represents medium-density suburban area
Velocity	692 kmph	NUREG-0170 (NRC 1977)
Crew/flight	3	NUREG-0170 (NRC 1977)
Crew exposure distance	15.2 m	NUREG-0170 (NRC 1977)
Passengers/flight	78	NUREG-0170 (NRC 1977)
Stop time	0.0008 h/km	PT-2370 (Neuhauser and Kanipe 1992)
Minimum stop time	2 h	SAND89-2370 (Neuhauser and Kanipe 1992)
Number of persons exposed at stops	1000	SAND89-2370 (Neuhauser and Kanipe 1992)
Exposure distance when stopped	50 m	SAND89-2370 (Neuhauser and Kanipe 1992)
Accident rate, takeoff/landing	2.8×10^{-6} per flight	Massey and Coats (1995)
Accident rate, in-flight	6.9×10^{-10} /km	Massey and Coats (1995)
Ci per package - molybdenum-99 - iodine-131 - xenon-133 - iodine-125	820 220 620 7	Massey and Coats (1995)
Transport Index (dose rate at 1 m from side of package) - molybdenum-99 - iodine-131 - xenon-133 - iodine-125	4.4 mrem/h ^(a) 0.6 mrem/h 0.14 mrem/h 0.6 mrem/h	NUREG-0170 (NRC 1977)
(a) Exceeds allowable (3.0 mrem/h) in 49 CFR 175 for passenger flights; therefore, may be required to be shipped by cargo air; use of passenger flights would bound public impacts.		

was assumed to be transferred at the carrier's central distribution hub to a second flight to the final destination; thus, two loading and unloading procedures were included in the analysis of each air shipment. The sum of these two procedures was modeled in RADTRAN as one handling.

Airport handler exposures were modeled in two ways, depending on the size of the package. For small packages (maximum dimension less than 0.5 m [1.6 ft]) such as the D-133 gas bottle, the dose to workers

is modeled as 2.5×10^{-4} rem/handling/TI (Madsen et al. 1986). Otherwise, the RADTRAN calculations were performed by multiplying the radiation dose rate, times the number of handlers, and length of exposure. In addition to the loading and unloading of aircraft, transit of the package through the airports was modeled as a stop that exposes 1000 persons at an average exposure distance of 50 m (164 ft).

Radiation exposures to air crews are calculated by RADTRAN using a simple model that uses an average exposure distance and number of exposed persons. The integrated crew exposure is calculated as the product of the dose rate at a specific distance from the source, the number of crew aboard the aircraft, and the transit time. The doses to aircraft passengers and flight attendants are calculated using an empirical value of 3×10^{-5} rem/h/TI (Madsen et al. 1986). The integrated exposures are the product of the number of shipments, TI value, number of exposed persons, the empirical TI-to-dose-rate conversion factor, and transit time.

The RADTRAN input parameters used in calculating the routine doses from the air transport legs of the isotope shipments are presented in Table B-4. The sources of the input data are also shown in the table.

Accident Impact Data. Potential accident environments are defined and their likelihood of occurrence are modeled using an approach that divides the entire spectrum of potential aircraft accident environments into six accident severity categories. The severity categories are based on event trees originally developed for spent fuel shipped by truck and rail (Wilmot 1981). The conditional probabilities of occurrence of each accident severity were developed from these data. The overall probability of an accident of a particular severity is calculated as the product of the base accident probability (accident rate) and the conditional probability. Accident rate data for aircraft accidents are shown in Table B-5. Accident rate data for air accidents are taken from Massey and Coats (1995)

The radionuclide release from which members of the public could receive a dose in the event of an accident depends on three factors in the event that a package fails and its protection is compromised. Release fractions define the fraction of the package inventory that would be released into the environment. Aerosol fraction defines the quantity of released material that would be lofted into the plume, and respirable fraction defines the quantity of aerosolized material that could be inhaled by human beings. These parameters are quantified for each type of radioactive material that would be shipped as part of the proposed action and are shown in Table B-6.

GENII Description. GENII (Napier et al. 1988), which is also referred to as the Hanford Environmental Dosimetry Software System, was developed to analyze radiological releases to the environment. GENII has been used to calculate the dose to MEIs (see Section B.1.3.1). GENII is composed of seven linked computer programs and their associated data libraries (Appendix C). This includes user interface programs, internal and external dose factor generators, and the environmental dosimetry programs.

Table B-5. RADTRAN Accident Impact Parameters for Air Shipments

Accident Rate - Air Takeoff/Landing - Air In-flight		$2.8 \times 10^{-6}/\text{flight}$ $6.9 \times 10^{-10}/\text{km}$		
Severity Category Parameters	Probability^(a)	Release Fraction^(b)	Aerosol Fraction^(c)	Respirable Fraction^(c)
Category 1	T; 0.208 I; 0.230	A; 0 B; 0	Xe; 0 Other; 0	Xe; 0 Other; 0
Category 2	T; 0.504 I; 0.130	A; 1 B; 0	Xe; 1 Other; 0	Xe; 1 Other; 0
Category 3	T; 0.050 I; 0.385	A; 1 B; 1	Xe; 1 Other; 0	Xe; 1 Other; 0
Category 4	T; 0.060 I; 0.014	A; 1 B; 1	Xe; 1 Other; 0	Xe; 1 Other; 0
Category 5	T; 0.128 I; 0.217	A; 1 B; 1	Xe; 1 Other; 1	Xe; 1 Other; 0.05
Category 6	T; 0.014 I; 0.024	A; 1 B; 1	Xe; 1 Other; 1	Xe; 1 Other; 0.05
(a) Conditional probability of encountering accident environment equivalent to Category 1 impact and thermal environments. Given for in-flight (I) and Takeoff/landing (T) portions of air trip. (b) Release fractions are the fraction of the package inventory release from the package and are given for Type A (A; includes Xe-133 and I-125) and Type B (B; including Mo-99 and I-131) packages for each severity category. (c) Aerosol and respirable fractions are the fractions of the released material that are in aerosol and respirable form, respectively, and are given separately for releases from Xe-133 and Other (Mo-99, I-125, and I-131) packages for each severity category.				

GENII is capable of

- calculating doses resulting from acute or chronic releases, including options for annual dose, committed dose, and accumulated dose
- calculating doses from various exposure pathways evaluated, including those through direct exposure via water, soil, and air, as well as inhalation and ingestion pathways
- acute and chronic elevated and ground level releases to air
- acute and chronic releases to water

Table B-6. Radiological Inventories by Material Type Used in Analyses

Radionuclide	Curies per Radionuclide by Package Shipped ^(a)			
	Unirradiated Target	Irradiated Target ^{(b)(c)}	Medical Isotopes ^(d)	Low-Level Waste ^{(e)(c)}
Chromium-51		27.6		16.1
Iron-55		37.2		21.7
Iron-59		1.37		0.8
Krypton-85		6,670		
Strontium-89		2,330		87.2
Strontium-90		13.9		60.8
Yttrium-91		2,260		130
Zirconium-95		2,470		156
Niobium-95		164		278
Molybdenum-99		26,400	820	
Technetium-99		231,000		
Ruthenium-103		1,920		35.8
Ruthenium-106		26.9		8.8
Tellurium-127		422		
Tellurium-129		3,000		
Tellurium-129m		64.8		
Iodine-125			7.0	
Iodine-131		6,530	220	
Xenon-133		18,500	620	
Cesium-137		10.8		6.32
Cerium-141		4,150		41.3
Cerium-144		185		139
Promethium-147		41.0		23.9
Uranium-Total		19,500		
Uranium-235	0.0011			
(a) Only those default radionuclides defined in RADTRAN 4 are used to characterize the irradiated target and low-level waste. Other radionuclides are not expected to contribute significantly to the dose consequences. Curie quantities shown are for one shipping package. (b) Taken from the LANL Environmental Assessment (LANL 1993e), October 1993, at 0 hours following irradiation - 24 irradiated targets per shipment. (c) Curies per radionuclide have been adjusted to 20 kW 7-day irradiation. (d) Each isotope is packaged and shipped separately. (e) Waste generated from 14 targets stored for 180 days.				

- initial contamination of soil or surfaces
- radionuclide decay.

The pathways considered in this analysis include inhalation, submersion, and external exposures due to ground contamination.

B.1.2 Routine or Incident-Free Transportation Impacts

The following sections describe expected radiological and nonradiological impacts during routine or incident-free transportation of unirradiated and irradiated targets, separated isotopes, and secondary waste products for each of the alternatives. The radiological inventories used in the analyses are shown in Table B-6.

B.1.2.1 Radiological Impacts From Transportation Activities

This section presents the analysis of the radiological impacts to the public and onsite individuals due to routine transportation. Members of the public or onsite individuals exposed to radiation include persons on onsite roads or offsite highways with the shipment, persons residing near these transport links, and persons at intermediate stops along the route (such as refueling stops). For air transport, it was assumed that all shipments would be made using commercial passenger flights; therefore, impacts to the public include airplane passengers and people in the airport terminals. This will result in conservative estimates, and will bound the air transport scenarios. The RADTRAN 4 computer code was used to perform these calculations. A description of RADTRAN 4 was presented in Section B.1.1.4. The following sections present the results of the incident-free exposure calculations.

The results of the public and onsite individual dose calculations, developed using the RADTRAN 4 computer code and the input parameters shown in Tables B-2, B-3, and B-4, are presented in Table B-7.

As shown in Table B-7, the radiological impacts to the combined truck and air transport crew range from 23 to 24 person-rem annually or 0.01 latent cancer fatalities (LCFs). The onsite and public radiological impacts range from 26 (ORNL) to 53 (INEL) person-rem annually or 0.01 to 0.03 LCFs. For shipments meeting 100% of the U.S. demand (i.e., 1035 shipments of Mo-99, xenon-133, and iodine-131 and 105 shipments of iodine-125 annually), the results are shown in Tables B-14 and B-16 for Nordion and the three U.S. distributors, respectively.

This action may require the transport of highly enriched uranium to the target fabrication facilities. Currently, all the sites except for SNL/NM have a sufficient supply of highly enriched uranium in storage to fabricate targets for 5 years or more. Consequently, no environmental impacts would be associated with transporting highly enriched uranium to these sites. For SNL/NM, approximately 25 kg of highly enriched uranium per year are estimated to be needed. The impacts of this were estimated based on information

presented in the DOE report (1995q). Preliminary unit risk values (person-rem/km per kg of highly enriched uranium shipped) were derived from the data presented in the DOE report (1995q). Based on the results in DOE 1995q for the option in which highly enriched uranium would be shipped from the Y-12 Plant to Erwin, Tennessee, for blending, the unit risk values were calculated to be 5×10^{-8} person-rem/km-kg for the public and 1.3×10^{-7} person-rem/km-kg for the truck crews. These values were multiplied by the approximate distance from Y-12 to SNL/NM (2200 km) and the annual highly enriched uranium requirements (25 kg/yr) to calculate the annual radiological exposures for the highly enriched uranium shipments needed by SNL/NM to fabricate the required targets. The resulting radiological exposures for incident-free transport were 3×10^{-3} person-rem/yr to the public and 7×10^{-3} person-rem/yr to the truck crews. These exposures are insignificant relative to the annual exposures presented in Table B-7.

Table B-7. Radiological Impacts Due to Routine or Incident-Free Transportation

Alternative	Radiological Impacts (person-rem/yr) ^(a)		Health Effects (LCFs/yr) ^(d)	
	Crew ^(b)	Public ^(c)	Crew ^(b)	Public ^(c)
Los Alamos Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	23 (1)	52 (0.08)	0.01	0.03
Los Alamos Target Fabrication and Irradiation and Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	24 (2)	52 (0.2)	0.01	0.03
Sandia National Laboratories Target Fabrication, Irradiation and Separations, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	24 (2)	52 (0.2)	0.01	0.03
Oak Ridge National Laboratory, Target Fabrication, Irradiation and Separations, Waste to Nevada Test Site, and Shipments from McGhee Tyson Airport	23 (2)	26 (0.2)	0.01	0.01
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	23 (1)	53 (0.05)	0.01	0.03
(a) Radiological impacts for truck transport are shown in parentheses. (b) Truck and air transport crew, including handlers at airports. (c) Includes public and onsite individuals where appropriate. (d) Latent cancer fatalities calculated in accordance with ICRP Publication 60 (ICRP 1991).				

Although not shown in Table B-7, the radiological impacts for air transport activities (assuming commercial passenger flights) account for more than 90% of the totals. This percentage is primarily due to the number of air shipments required annually, and the number of passengers exposed during the entire flight. However, the calculated dose to an individual passenger is approximately 0.7 mrem/shipment,

which is negligible when compared to the dose received by the average U.S. citizen from both natural and artificial sources (approximately 360 mrem/yr). In addition, as reported in NCRP Report No. 93 (NCRP 1987), the average aircraft passenger, on flights not transporting radioactive materials, receives approximately 0.5 mrem/h, due to cosmic radiation. For comparison, it was assumed that, on the average, it would take approximately 4 h for the entire flight; therefore, passengers on the flight would receive approximately 2 mrem due to cosmic radiation. This dose is roughly two times that received due to transporting medical isotopes.

Assuming the medical isotopes are shipped air cargo and the cask dose rates remain the same, the crew impacts would remain approximately the same; however, impacts to the public (such as passengers and people in the airport terminal) would be significantly lower (less than 1 person-rem/yr). Also, increases in the cask dose rate (greater than 4.4 mrem/h) would increase crew impacts. However, this increase would not change the impacts to the public (that is, remain less than 1 person-rem/yr).

B.1.2.2 Nonradiological Impacts from Transportation Activities

Impacts to the public from nonradiological causes are also evaluated. These impacts include fatalities resulting from pollutants emitted from the vehicles during normal transportation. Based on the information contained in Rao et al. (1982), the types of pollutants that are present and can impact the public are sulfur oxides (SO_x), particulates, nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons (HC), and photochemical oxidants (O_x). Of these pollutants, this report determined the majority of the health effects are due to SO_x and the particulates. Unit risk factors (fatalities per kilometer) for truck shipments were developed by Rao et al. (1982) for travel in urban population zones ($1 \times 10^{-7}/\text{km}$ for truck).

Table B-8 presents the results of the incident-free or routine nonradiological impacts. It also shows that impacts to the public (not including onsite individuals) are essentially the same or 0.008 to 0.009 fatalities. For shipments meeting 100% of the U.S. demand (i.e., 1035 shipments of Mo-99, xenon-133, and iodine-131 and 105 shipments of iodine-125 annually), the results are shown in Tables B-14 and B-16 for Nordion and the three U.S. distributors, respectively.

B.1.3 Transportation Accident Impacts

Radiological and nonradiological transportation accident impacts during transportation of unirradiated and irradiated targets, separated isotopes, and secondary waste products for each of the alternatives are discussed in the following sections.

B.1.3.1 Radiological Impacts Due to Transportation Accidents

Radiological impacts are calculated for the public, as well as the MEI. The impacts to the public are presented in this section as integrated population risks (that is, accident frequencies multiplied by consequences integrated over route-specific population, for a 1-year shipping campaign). The impacts to the public and MEI are based on the radiological inventories shown in Table B-6.

Table B-8. Nonradiological Impacts to the Public Due to Routine or Incident-free Transportation

Alternative	Fatalities/yr
Los Alamos Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	0.008
Los Alamos Target Fabrication and Irradiation and Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	0.009
Sandia National Laboratories Target Fabrication, Irradiation and Separations, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	0.009
Oak Ridge National Laboratory, Target Fabrication, Irradiation and Separations, Waste to Nevada Test Site, and Shipments from McGhee Tyson Airport	0.009
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	0.008

Population risk calculations were performed using the RADTRAN 4 computer code (Neuhauser and Kanipe 1992) (see B.1.1.4). The MEI doses have been calculated using GENII (Napier 1988) (see also B.1.1.4).

Integrated Population Risk Assessment. For this analysis, risk is defined as the product of the frequency of occurrence of an accident involving a shipment and the consequences of an accident. Consequences are expressed in terms of the radiological dose and latent cancer fatalities from a release of radioactive material from the shipping cask or the exposure of persons to radiation that could result from damaged package shielding. The frequency of a transportation accident that involves radioactive materials is expressed in terms of the expected number of accidents per unit distance integrated over the total distance traveled. The response of the shipping cask to the accident environment and the probability of release or loss of shielding is related to the severity of the accident.

The frequencies of occurrence of transportation accidents that would release significant quantities of radioactive material are relatively small because the shipping casks are designed to withstand certain transportation accident conditions (that is, the shipping casks for all the materials shipped in this analysis were assumed to meet the Type B packaging requirements specified in 49 CFR 173 and 10 CFR 71). Accidents on the road are difficult to totally eliminate. However, because the shipping casks are capable of withstanding certain accident environments, including mechanical and thermal stress, only a relatively small fraction of accidents involve conditions that are severe enough to result in a release of radioactive materials.

Should an accident involving a shipment occur, a release of radioactive material could occur only if the cask were to fail. A failure would most likely be a small gap in a seal or small split in the containment vessel. For the radioactive material to reach the environment, it would have to pass through the split in the cask or through the failed seal. Materials released to the environment would be dispersed and diluted by

weather action and a fraction would be deposited on the ground (drop out of the contaminated plume) in the surrounding region. Emergency response crews arriving on the scene would evacuate and secure the area to exclude bystanders from the accident scene. The released material would then be cleaned up using standard decontamination techniques, such as excavation and removal of contaminated soil. Monitoring of the area would be performed to locate contaminated areas and to guide cleanup crews in their choice of protective clothing and equipment (for example, fresh-air equipment, or filtered masks). Access to the area would be restricted by federal or state radiation control agencies until it had been decontaminated to safe levels.

The RADTRAN 4 computer code was used to calculate the radiological risk of transportation accidents involving radioactive material shipments. The RADTRAN 4 methodology was summarized previously. For further details, refer to the discussions presented in Madsen et al. (1986) and Neuhauser and Kanipe (1992).

The five major categories of input data needed to calculate potential accident transportation risk impacts using the RADTRAN 4 computer code are 1) accident frequency, 2) release quantities, 3) atmospheric dispersion parameters, 4) population distribution parameters, and 5) human uptake and dosimetry models. Accident frequency and release quantities are discussed as follows; the remaining parameters have been discussed in previous sections.

Accident Frequency. The frequency of a severe accident is calculated by multiplying an overall accident rate (accidents per truck-kilometer) by the conditional probability that an accident would involve mechanical or thermal conditions that are severe enough to result in container failure and subsequent release of radioactive material. Overall accident rates per kilometer of truck or rail travel were taken from Saricks and Kvitek (1994). State-specific accident rates were used in this study.

For this analysis, six shipment-specific severity categories were defined, with category 1 as the least severe and the higher categories (2-6) representing increasingly severe conditions. The conditional probabilities of encountering accident conditions in each severity category were taken from a U.S. Nuclear Regulatory Commission (NRC) document (Fischer et al. 1987), which were developed based on reviews of accident records and statistics compiled by various state and federal agencies. The conditional probability for a given severity category is defined as the fraction of accidents that would fall into that severity category if an accident were to occur. The conditional probabilities were determined using a binning process.

As discussed previously, severity category levels were defined to model the response of the various shipments to accidents. Severity category 1 was defined as encompassing all accidents that are within the Type B Package envelope, which would not be severe enough to result in failure of the shipping cask (such as, accidents with zero release). The higher categories (2-6) were defined to include more severe accidents and thus may lead to a release of radioactive material. The derivation of the severity category schemes and conditional probabilities of accidents in each severity category are discussed following for each shipping cask or container type. Table B-9 presents the conditional probabilities of the various severity categories used in this analysis.

Table B-9. Accident Severity Categories and Conditional Probabilities^(a)

Mode/Truck	Conditional Probability by Severity Category					
	1	2	3	4	5	6
Rural	0.603	0.394	3×10^{-6}	3×10^{-6}	5×10^{-6}	7×10^{-6}
Suburban	0.602	0.394	0.004	4×10^{-6}	3×10^{-6}	2×10^{-6}
Urban	0.604	0.395	0.00038	3.8×10^{-7}	2.5×10^{-7}	1.3×10^{-7}
(a) Taken from Massey and Coats (1995).						

Release Fractions. Release fractions are used to determine the quantity of radioactive material released to the environment as a result of an accident. The quantity of material released is a function of the severity of the accident (that is, the thermal and mechanical conditions produced in the accident), the response of the shipping container to these conditions, and the physical and chemical properties of the material being shipped. The basis for the release fractions used in this analysis are discussed following and summarized in Table B-10. The results of the integrated population risk assessment are presented in Table B-11.

Table B-10. Release Fractions Used for Assessment of Accident Impacts

Material	Release Fraction by Severity Category					
	1	2	3	4	5	6
Spent Fuel^(a)						
Gases	0	0.0099	0.033	0.39	0.33	0.63
Cesium	0	1.1×10^{-7}	3.5×10^{-7}	6.0×10^{-6}	3.5×10^{-6}	6.0×10^{-5}
Ruthenium	0	4.1×10^{-9}	1.4×10^{-8}	2.4×10^{-7}	1.4×10^{-7}	2.4×10^{-6}
Particles	0	3.0×10^{-10}	1.0×10^{-9}	1.0×10^{-8}	1.0×10^{-8}	1.0×10^{-7}
Separated Isotopes^(b)						
Mo-99, I-131	0	1	1	1	1	1
Xe-133, I-125	0	1	1	1	1	1
Secondary Waste^(b)						
	0	0	0	1.0×10^{-8}	5.0×10^{-8}	5.0×10^{-8}
(a) These release fractions were applied to truck shipments of both unirradiated and irradiated targets (Massey and Coats 1995).						
(b) Taken from Massey and Coats (1995).						

The radiological impacts to the public (including onsite individuals) associated with truck transportation accidents range from 0.02 person-rem/yr (ORNL alternative) to 0.04 person-rem/yr (LANL and INEL alternative) (see Table B-11). The projected potential health effects range from 1×10^{-5} to 3×10^{-5} LCFs. For shipments to Nordion and the three U.S. distributors, the results shown in Tables B-15 and B-17, respectively, are for 100% of the annual U.S. demand.

Table B-11. Radiological Risk Due to Transportation Accidents, Including Truck and Air Transport

Alternative	Public ^(a)	
	Radiological Risk ^(b) (person-rem/yr)	Health Effects (LCFs) ^(c)
Los Alamos Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	0.04 (5×10^{-1})	2×10^{-5}
Los Alamos Target Fabrication and Irradiation and Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	0.04 (2×10^{-3})	2×10^{-5}
Sandia National Laboratories Target Fabrication, Irradiation and Separations, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	0.04 (2×10^{-3})	2×10^{-5}
Oak Ridge National Laboratory, Target Fabrication, Irradiation and Separations, Waste to Nevada Test Site, and Shipments from McGhee Tyson Airport	0.02 (8×10^{-4})	1×10^{-5}
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	0.04 (5×10^{-4})	2×10^{-5}
(a) Includes public and onsite individuals where appropriate. (b) Radiological risk for truck transport shown in parentheses. (c) Latent cancer fatalities calculated in accordance with ICRP Publication 60 (ICRP 1991).		

Results of Transportation Accident Impacts to a Maximally Exposed Individual. In addition to the radiological dose to the public, the doses to a MEI were calculated. It is assumed that a vehicle accident that would result in a release (catastrophic cask failure) would result in crew fatalities; therefore, radiological impacts to the crew were not calculated. The individual was assumed to be located 100 m (328 ft) from the accident.

Radiological accident impacts to the MEI are calculated using GENII (Napier 1988). To calculate the impacts to the receptor, it was assumed the release due to a catastrophic failure of the shipping cask was at ground level.

The radiological dose to the MEI located 100 m (328 ft) from a truck transportation accident, by material, is shown in Table B-12. As shown, the dose received due to an accident involving a shipment of iodine-131 is greater than all other calculated doses.

Table B-12. Accidental Releases and Dose to the Maximally Exposed Individual Located 100 m from Transport Accident

Isotope/ Material	Unirradiated Target	Irradiated Target	Mo-99	I-125	I-131	Xe-133	Waste
Qty. of Material ^(a)	0.0011	one shipment	41.0 Ci	0.35 Ci	11.0 Ci	31.0 Ci	one shipment
Dose (rem)	0.91	1.3	0.62	0.054	2.6	0.063	1.4 x 10 ⁻⁶
(a) With the exception of the irradiated target and waste, the quantities shown are respirable.							

B.1.3.2 Non-Radiological Impacts from Transportation Accidents

This section describes the analyses performed to assess non-radiological impacts to the public. Nonradiological accident impacts are the fatalities resulting from potential vehicular accidents involving the shipments. It is assumed that a vehicle accident that would result in a release from a shipping cask could also result in crew fatalities; therefore, nonradiological vehicular accident impacts are calculated for the public and transport crew.

Manual calculations were performed using unit-risk factors (fatalities per km of travel) to derive estimates of the nonradiological impacts. The nonradiological impacts were calculated by multiplying the unit risk factors by the total shipping distances for all of the shipments in each shipping option. Nonradiological unit risk factors for vehicular accidents were taken from Saricks and Kvitek (1994) (public). These risk factors, in units of fatalities-per-km of travel in rural suburban, and urban population zones, were multiplied by the total distance traveled in each zone by all of the shipments and then summed to calculate the expected number of nonradiological accidental fatalities. The unit risk factor for travel in suburban zones was represented by the average of the rural and urban unit risk factors given by Saricks and Kvitek (1994).

The results of the nonradiological accident impact calculations for the five potential shipping scenarios are presented in Table B-13. The values reported in the table, 0.01 to 0.02 fatalities, represent the sum of the impacts from all of the shipments and include the impacts from shipments carrying cargo, as well as those from empty return shipments. For shipments to Nordion and the three U.S. distributors, the results shown in Tables B-15 and B-17, respectively, are for 100% of the annual U.S. demand.

Table B-13. Nonradiological Impacts Due to Truck Transportation Accidents

Alternative	Fatalities/yr
Los Alamos Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	0.02
Los Alamos Target Fabrication and Irradiation and Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	0.01
Sandia National Laboratories Target Fabrication, Irradiation and Separations, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	0.01
Oak Ridge National Laboratory, Target Fabrication, Irradiation and Separations, Waste to Nevada Test Site, and Shipments from McGhee Tyson Airport	0.02
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	0.01

Table B-14. Routine Transportation Impacts for Shipments of 100% of the U.S. Demand to Nordion in Ottawa, Canada

Alternative	Radiological Impacts ^(a)				Non-Radiological Impacts ^(b)
	Radiological Impacts (person-rem/yr) ^(c)		Health Effects (LCFs) ^(d)		Fatalities/yr
	Crew	Public	Crew	Public	Public
Los Alamos Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	23	69	0.01	0.04	0.008
Los Alamos Target Fabrication and Irradiation, Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	23	69	0.01	0.04	0.009
Sandia National Laboratories Target Fabrication, Irradiation, Separations, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	23	69	0.01	0.04	0.009
Oak Ridge National Laboratory Target Fabrication, Irradiation, Separations, Waste to Nevada Test Site, and Shipments from McGhee Tyson Airport	21	33	0.01	0.02	0.009
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	22	45	0.01	0.02	0.008
(a) Radiological Impacts calculated using the methodology described in Section B.1.2.1. (b) Nonradiological Impacts calculated using the methodology described in Section B.1.2.2. (c) Crew - includes truck and air crews and handlers at hubs; Public - includes public and onsite individuals where appropriate. (d) Latent cancer fatalities (LCFs) calculated in accordance with ICRP Publication 60 (ICRP 1991).					

Table B-15. Transportation Accident Impacts for Shipments of 100% of the U.S. Demand to Nordion in Ottawa, Canada

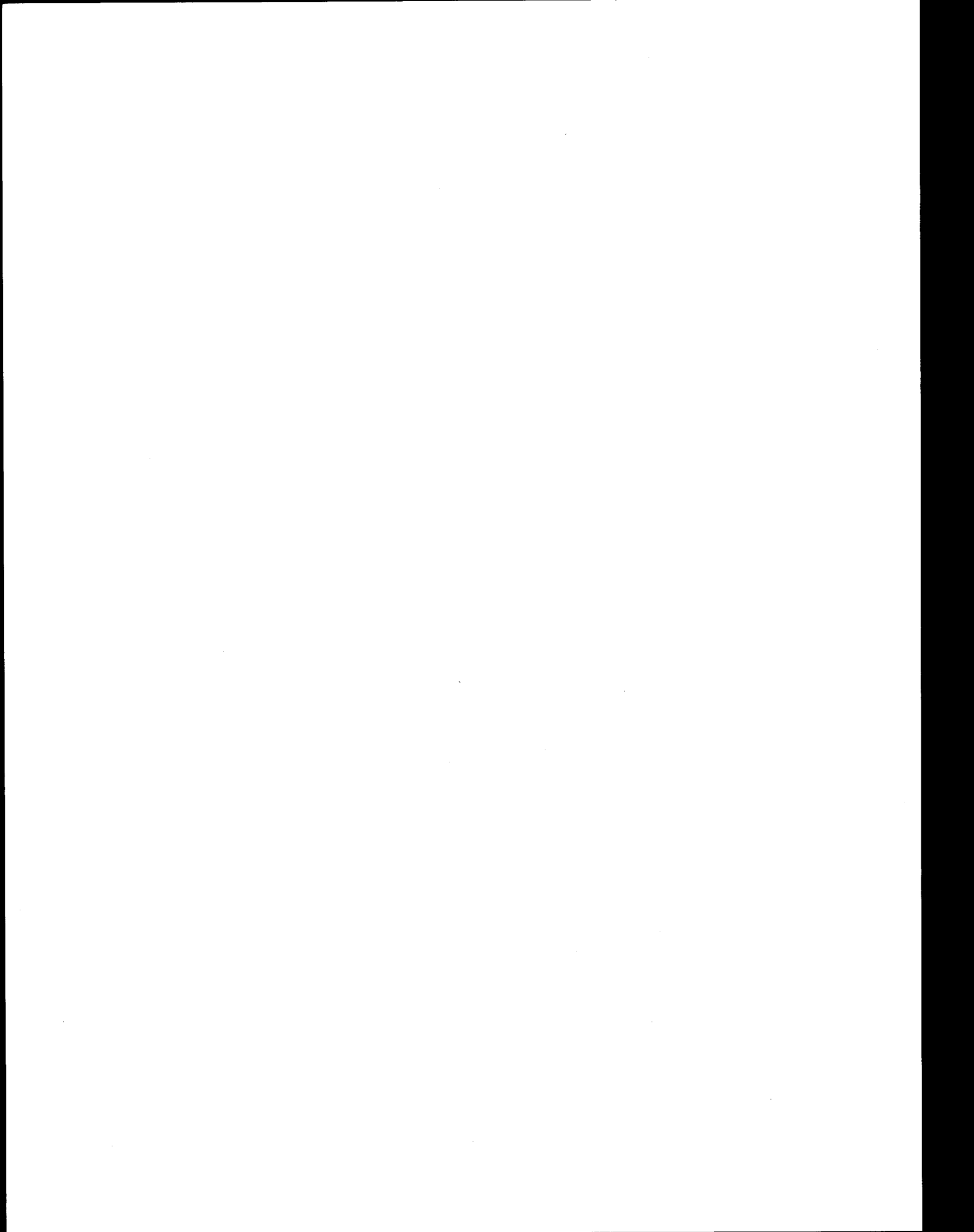
Alternative	Radiological Impacts to the Public ^(a)		Non-Radiological Impacts ^(b)
	Radiological Impacts (person-rem/yr) ^(c)	Health Effects (LCFs) ^(d)	Fatalities/yr
Los Alamos Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	0.05	2×10^{-5}	0.02
Los Alamos Target Fabrication and Irradiation, Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	0.05	2×10^{-5}	0.01
Sandia National Laboratories Target Fabrication, Irradiation, Separations, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	0.05	2×10^{-5}	0.01
Oak Ridge National Laboratory Target Fabrication, Irradiation, Separations, Waste to Nevada Test Site, and Shipments from McGhee Tyson Airport	0.02	1×10^{-5}	0.02
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	0.03	2×10^{-5}	0.01
(a) Radiological Impacts calculated using the methodology described in Section B.1.3.1. (b) Nonradiological Impacts calculated using the methodology described in Section B.1.3.2. (c) Public - includes public and onsite individuals where appropriate. (d) Latent cancer fatalities (LCFs) calculated in accordance with ICRP Publication 60 (ICRP 1991).			

Table B-16. Routine Transportation Impacts for Shipments of 100% of the U.S. Demand to U.S. Distributors

Alternative	Destination	Radiological Impacts ^(a)				Non-Radiological Impacts ^(b)
		Radiological Impacts (person-rem/yr) ^(c)		Health Effects (LCFs) ^(d)		Fatalities/yr
		Crew	Public	Crew	Public	Public
Los Alamos Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	Dupont-Merck	24	69	0.01	0.04	0.008
	Amersham Mediphsysics	22	39	0.01	0.02	0.02
	Mallinckrodt Medical	23	48	0.01	0.02	0.004
Los Alamos Target Fabrication and Irradiation, Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	Dupont-Merck	24	69	0.01	0.04	0.009
	Amersham Mediphsysics	22	39	0.01	0.02	0.01
	Mallinckrodt Medical	23	48	0.01	0.02	0.005
Sandia National Laboratories Target Fabrication, Irradiation, Separations, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	Dupont-Merck	24	69	0.01	0.04	0.009
	Amersham Mediphsysics	22	39	0.01	0.02	0.01
	Mallinckrodt Medical	23	48	0.01	0.02	0.005
Oak Ridge National Laboratory Target Fabrication, Irradiation, Separations, Waste to Nevada Test Site, and Shipments from McGhee Tyson Airport	Dupont-Merck	23	33	0.01	0.02	0.009
	Amersham Mediphsysics	23	24	0.01	0.01	0.01
	Mallinckrodt Medical	22	22	0.01	0.01	0.005
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	Dupont-Merck	24	72	0.01	0.04	0.008
	Amersham Mediphsysics	23	45	0.01	0.02	0.01
	Mallinckrodt Medical	22	42	0.01	0.02	0.004
(a) Radiological Impacts calculated using the methodology described in Section B.1.2.1 (b) Nonradiological Impacts calculated using the methodology described in Section B.1.2.2 (c) Crew - includes truck and air crews and handlers at hubs; Public - includes public and onsite individuals where appropriate (d) Latent cancer fatalities (LCFs) calculated in accordance with ICRP60 (ICRP 19).						

Table B-17. Transportation Accident Impacts for Shipments of 100% of the U.S. Demand to U.S. Distributors

Alternative	Destination	Radiological Impacts to the Public ^(a)		Non-Radiological Impacts ^(b)
		Radiological Impacts (person-rem/yr) ^(c)	Health Effects (LCFs) ^(d)	Fatalities/yr
Los Alamos Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Albuquerque International Airport	Dupont-Merck	0.05	2×10^{-5}	0.02
	Amersham Mediphsics	0.03	1×10^{-5}	0.02
	Mallinckrodt Medical	0.03	2×10^{-5}	0.01
Los Alamos Target Fabrication and Irradiation, Separations at Sandia National Laboratories, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	Dupont-Merck	0.05	3×10^{-5}	0.01
	Amersham Mediphsics	0.03	2×10^{-5}	0.02
	Mallinckrodt Medical	0.04	2×10^{-5}	0.009
Sandia National Laboratories Target Fabrication, Irradiation, Separations, Waste to Nevada Test Site, and Shipments from Albuquerque International Airport	Dupont-Merck	0.05	3×10^{-5}	0.01
	Amersham Mediphsics	0.03	2×10^{-5}	0.01
	Mallinckrodt Medical	0.04	2×10^{-5}	0.008
Oak Ridge National Laboratory Target Fabrication, Irradiation, Separations, Waste to Nevada Test Site, and Shipments from McGhee Tyson Airport	Dupont-Merck	0.02	1×10^{-5}	0.02
	Amersham Mediphsics	0.02	1×10^{-5}	0.02
	Mallinckrodt Medical	0.02	1×10^{-5}	0.02
Idaho National Engineering Laboratory Target Fabrication, Irradiation, Separations, Onsite Waste Storage, and Shipments from Idaho Falls Airport	Dupont-Merck	0.05	3×10^{-5}	0.01
	Amersham Mediphsics	0.03	2×10^{-5}	0.01
	Mallinckrodt Medical	0.03	2×10^{-5}	0.007
(a) Radiological Impacts calculated using the methodology described in Section B.1.3.1 (b) Nonradiological Impacts calculated using the methodology described in Section B.1.3.2 (c) Public - includes public and onsite individuals where appropriate (d) Latent cancer fatalities (LCFs) calculated in accordance with ICRP60 (ICRP 19).				



Appendix C

Input to GENII Calculations for all Alternatives

Appendix C

Input to GENII Calculations for all Alternatives

Where appropriate, site-specific parameters were used in the analyses for radiological impacts. The complete set of site-specific parameters is shown in Table C-1. This table lists the site, and the facility for each process. Associated with that site is a population file, and a joint frequency distribution file of meteorological conditions averaged over time, as well as food production data where known. Printouts of these files containing the data follow Table C-1. Where input data went directly into the calculations (for example, distance and direction to the maximally exposed individual [MEI] or release height), the data are listed in Table C-1.

The tables in this appendix contain the values used in running GENII for this document. The three sets of tables include population distributions by directions and distance; wind by direction, wind speed, and wind stability; and food production by direction and distance. In all of the tables, the compass is divided into 16 sectors starting with the south and continuing clockwise to SSE. In each of the sections, the sites are listed in the same order: Sandia National Laboratories/New Mexico (SNL/NM); Los Alamos National Laboratory (LANL) TA-2; LANL TA-3; Oak Ridge National Laboratory (ORNL); and Idaho National Engineering Laboratory (INEL).

Table C-1. Site-Specific Parameters Used in Radiologic Calculations

Site	Operation/Scenario	Facility	Population File	Joint Frequency Distribution	Normal Operations: Onsite MEI	Accidents: Onsite MEI	Offsite MI	Nearest Public Access	Accidents:Pop Wted Sector	Stack Height (m)	Inner Radius (m)	Flow Rate (m ³ /s)
SNL/NM	Fabrication	Hot Cells	acrrpop.90	jfsnl15.5yr	1.6 km NW	300 m N	5400 m N	5400 m N	North n=133,266	38.1	0.9	22.1
	Irradiation: Normal Operation/Fuel Element Rupture/Target Rupture	ACRR	acrrpop.90	jfsnl15.5yr	1.6 km NW	300 m N	5400 m N	5400 m N	North n=133,266	16.5	0.1	0.35
	Transfer: Mo-99 Target Rupture	ACRR to Hot Cells	acrrpop.90	jfsnl15.5yr	1.6 km NW	300 m N	5400 m N	5400 m N	North n=133,266	Ground Level		
	Processing: Normal Operation/Operator Error for Mo-99, I-125 Targets	Hot Cells	acrrpop.90	jfsnl15.5yr	1.6 km NW	300 m N	5400 m N	5400 m N	North n=133,266	38.1	0.9	22.1
LANL	Fabrication	Hot Cells/CMR	ta3pop.93	jfta6-10.5yr	200 m E	200 m NNW	990 m E	200 m E	ENE n=26760	16.6	2.6	52.9
	Irradiation: Normal Operation/Fuel Element Melt/Target Rupture	Omega West	ta2pop.93	jfta6-10.5yr	650 m W	200 m NNW	580 m NNW	300 m N	NW n=4743	45.7	0.1	0.38
	Transfer to Casks: Target Rupture	Omega West	ta2pop.93	jfta4110.1yr	N/A	200 m NNW	1300 m N	300 m N	NW n=4743	Ground Level		
	Processing: Normal Operation/Operator Error for Mo-99, I-125 Targets	Hot Cells/CMR	ta3pop.93	jfta6-10.5yr	200 m E	100 m W	990 m N	100 m W	ENE n=26760	16.6	2.6	52.9
ORNL	Fabrication	Hot Cells X-3047	orlpop.92	jfx10-10.10yr	4.1 km SSW	300 m W	5450 m E	400 m NE	East n=241,081	76.2	2.85	66.4
	Irradiation: Normal Operation/Fuel Element Melt/Target Rupture	ORNL X-3039	orlpop.92	jfx10-10.10yr	4.1 km SSW	300 m W	5450 m E	400 m NE	East n=241,081	76.2	2.85	66.4
	Transfer: Mo-99 Target Rupture	BSR X-3039	orlpop.92	jfx10-10.10yr	N/A	300 m W	5450 m E	400 m NE	East n=241,081	76.2	2.85	66.4
	Processing: Normal Operation/Operator Error for Mo-99, I-125 Targets	Hot Cells X-3047	orlpop.92	jfx10-10.10yr	4.1 km SSW	300 m W	5450 m E	400 m NE	East n=241,081	76.2	2.85	66.4

Table C-1. (contd)

Site	Operation/Scenario	Facility	Population File	Joint Frequency Distribution	Normal Operations: Onsite MEI	Accidents: Onsite MEI	Offsite MI	Nearest Public Access	Accidents: Pop Wted Sector E/Q	Stack Height (m)	Inner Radius (m)	Flow Rate (m ³ /s)
INEL	Fabrication	Hot Cell Facility	pbfpop.93	jfpbf10.5yr	1600 m ESE	200 m S	12.4 km SE	1000 m SSE	East n=70,150	10 m assumed		
	Irradiation: Normal Operation/Fuel Element Melt/Target Rupture	Power Burst Facility	pbfpop.93	jfpbf10.5yr	1600 m ESE	200 m S	12.4 km SE	1000 m SSE	East n=70,150	24.4	0.45	2.8
	Transfer: Mo-99 Target Rupture	Power Burst Facility	pbfpop.93	jfpbf10.5yr	1600 m ESE	200 m S	12.4 km SE	1000 m SSE	East n=70,150	Ground Level		
	Processing: Normal Operation/Operator Error for Mo-99, I-125 Targets	Hot Cell Facility	pbfpop.93	jfpbf10.5yr	1600 m ESE	200 m S	12.4 km SE	1000 m SSE	East n=70,150	10 m assumed		
Dismissed:												
U of MO		Fabrication at Gulf Atomics										
		MURR	murrpop.90	STAR data in hand								
		Processing at AECL										
		Processing at a US hot cell										
		HFIR @ORNL Bldg 7911	orlpop.92	jfx 10-10.10yr		4540 m ENE	5160 m WSW			30 m MT4		

C.1 Population Distribution Tables

Tables C-2 to C-6 show the number of people living near the site by compass direction (rows) from the site and by distance from the site (columns). Each distribution is centered on or near the facility specified in the file table. The most recent data available are reported. All SNL/NM facilities used the same population files.

The Omega West Reactor and Chemistry and Metallurgy Research Facility at LANL are separated, thus they have slightly different population distributions. As shown in Table C-1, the Chemistry and Metallurgy Research Facility used the population distribution for TA-3, while Omega West Reactor's population distribution centered on TA-2.

The population distribution was the same for both Oak Ridge Research Reactor and the hot cell facilities because the two are so close to each other.

Because the exact location of the INEL hot cells were unknown at the time of this writing, it was assumed the hot cells would be constructed in the vicinity of the Power Burst Facility (PBF), thus, the PBF population file was used to represent the hot cells, as well as the reactor.

Table C-2. Sandia National Laboratories/New Mexico Population Grid Based on 1990 Census Data
Total = 606718

(created [9-14-95] lhs;
distance in miles from site)

Miles/ Sector	1	2	3	4	5	10	20	30	40	50	Total
S	0	0	0	159	5	105	1493	38	173	436	2409
SSW	0	0	0	147	28	97	6688	15339	2559	580	25438
SW	0	0	82	55	65	97	16770	3375	74	77	20595
WSW	0	0	41	55	71	2345	1273	376	18	3	4182
W	0	0	39	55	71	9118	5407	259	129	0	15078
WNW	0	0	92	76	409	22551	26093	283	572	6	50082
NW	0	0	123	397	1526	48374	55127	811	14	19	106391
NNW	0	0	123	264	4598	72184	65639	11440	568	1658	156474
N	393	1159	1227	359	2148	79235	36726	8702	1844	1473	133266
NNE	0	0	0	963	4832	37896	5384	1384	2297	4966	57722
NE	0	0	0	216	852	2382	4157	820	700	3860	12987
ENE	0	0	0	859	139	452	3459	1809	333	296	7347
E	0	0	0	0	81	445	2131	3505	743	160	7065
ESE	0	0	0	0	135	344	1155	969	1150	290	4043
SE	0	0	0	0	213	123	178	412	662	199	1787
SSE	0	0	0	0	59	95	247	224	1096	131	1852

Table C-3. Los Alamos National Laboratory TA-2 Omega West Reactor 1993 Projection Based on 1990 Data Total = 236825

(distances in kilometers)

km/ Sector	1	2	4	8	15	20	30	40	60	80	Total
S	4	15	0	0	45	1	584	1200	3684	3348	8881
SSW	4	15	0	2	1	1	116	145	3001	54157	57442
SW	4	15	0	1	5	0	0	30	3478	4	3537
WSW	67	141	5	0	2	2	276	598	452	5	1548
W	28	54	127	0	1	17	62	218	44	129	680
WNW	57	399	1962	56	0	1	33	25	200	2234	4967
NW	247	357	2242	834	0	4	28	66	494	471	4743
NNW	314	380	515	1	0	7	0	148	150	248	1763
N	124	408	348	0	0	15	82	811	542	551	2881
NNE	39	326	461	50	0	14	741	477	879	332	3319
NE	43	312	517	236	1	3	9539	2527	2104	1063	16345
ENE	7	53	319	83	22	422	11486	3868	1815	2346	20421
E	8	24	120	2	179	1371	4631	505	28	239	7107
ESE	1	0	21	3	868	2	307	11351	2871	2657	18081
SE	0	14	25	0	5117	0	116	60384	11565	765	77986
SSE	4	17	2	0	52	0	4	3262	3560	223	7124

Table C-4. Los Alamos National Laboratory TA-3 Chemistry and Metallurgy Research Facility Total = 250889

(Building B3-29 Area Population from 1990 Census Estimated for 1993;
Created 05/26/95, Radian Corporation;
distances in kilometers)

km/ Sector	1	2	4	8	15	20	30	40	60	80	Total
S	0	0	0	3	1	1	1054	2390	2445	5853	11747
SSW	0	0	0	3	1	0	17	0	2889	65919	68829
SW	0	0	0	2	3	0	0	277	3294	3	3579
WSW	0	0	0	0	0	6	284	629	353	20	1292
W	0	0	0	0	9	21	183	70	62	322	667
WNW	0	0	0	0	0	9	42	22	969	1412	2454
NW	0	22	0	0	0	2	21	98	569	384	1096
NNW	0	348	94	0	0	9	7	111	152	171	892
N	1	738	2296	5	0	7	56	677	301	624	4705
NNE	3	437	1524	91	0	8	140	906	1112	380	4601
NE	5	409	1191	883	0	2	4703	3666	2431	497	13787
ENE	4	78	1180	1635	5	162	13952	5168	1665	2913	26762
E	1	194	62	174	2	485	4108	2274	78	126	7504
ESE	1	13	42	32	5451	0	92	16144	14043	3136	38954
SE	0	0	0	0	581	0	2	34818	23979	472	59852
SSE	0	0	0	0	52	0	13	1261	2571	271	4168

Table C-5. Oak Ridge National Laboratory 1992 Projected Population Based on 1990 Census Data Total
= 905740

(ORNL Population ORNL 1992 Annual Rpt. LHS [8/10/95]
distances in meters from site)

Meters/ Sector	100	200	300	2400	6400	12000	24000	40000	56000	72000	Total
S	0	0	0	0	100	2525	11108	8028	9295	4107	35163
SSW	0	0	0	0	67	1027	3429	10559	23037	15157	53276
SW	0	0	0	0	5	1148	3022	3882	6718	11785	26560
WSW	0	0	0	0	0	1566	12243	9186	5749	5162	33906
W	0	0	0	0	34	1591	9701	2099	15321	13190	41936
WNW	0	0	0	3	419	923	3501	1589	2576	4948	13959
NW	0	0	0	34	563	2163	4450	2240	2935	8642	21027
NNW	0	0	0	1442	1056	1904	977	1033	9509	5399	21320
N	0	0	0	289	2297	2570	752	2360	2695	8164	19127
NNE	0	0	0	18	4185	5279	5881	14059	16255	7466	53143
NE	0	0	0	0	1775	13940	16275	8906	5534	7014	53444
ENE	0	0	0	0	0	2374	31245	56253	16797	18605	125274
E	0	0	0	0	7	3415	85356	105705	23801	22797	241081
ESE	0	0	0	0	172	8215	32223	37569	9125	12574	99878
SE	0	0	0	0	240	4522	9745	30233	1242	824	46806
SSE	0	0	0	0	1	3009	8518	5115	1841	1356	19840

Table C-6. Idaho National Engineering Laboratory Power Burst Facility Population Grid Based on 1993 Annual Report Total = 121455

(80 km [created 18 August 1995 LHS]
distances in meters)

Meters/ Sector	800	2400	4000	5600	7200	12000	24000	40000	56000	72000	Total
S	0	0	0	0	0	0	0	0	0	2960	2960
SSW	0	0	0	0	0	0	0	0	0	160	160
SW	0	0	0	0	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0	0	0	120	120
W	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	2600	0	1200	3800
NW	0	0	0	0	0	0	0	0	0	10	10
NNW	0	0	0	0	0	0	352	0	0	15	340
N	0	0	0	0	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0	0	0	90	90
NE	0	0	0	0	0	0	0	0	0	2400	2400
ENE	0	0	0	0	0	0	0	0	0	11530	11530
E	0	0	0	0	0	0	0	0	1750	68400	70150
ESE	0	0	0	0	0	0	0	0	0	3050	3050
SE	0	0	0	0	0	25	0	0	8150	12450	20625
SSE	0	0	0	0	0	2300	0	0	0	3920	6220

C.2 Wind Speed/Wind Stability Tables

Tables C-7 through C-11 give the meteorologic data representing the frequency the wind blows in each direction and pasquill stability class. The tables are organized in terms of the compass direction the wind is blowing, starting in the south and moving clockwise in 16 sectors, and a scale is included that combines wind speed and pasquill wind stability category. The wind speed categories are from 1 through 6 (7 for INEL) and the stability categories are A through F (G for ORNL).

Meteorological data are represented in the joint frequency distribution tables. These tables show the percent of the time the wind blows in a given direction, within a given range of wind speeds, and during a given atmospheric stability class (A-F or G). These data are frequently averaged over several years. The midpoint of a wind speed is chosen to represent each wind speed range.

Joint frequency distributions are specific to each location and even release height; however, data are limited to collection points. The nearest collection point was used as the best available data. For SNL/NM, this meant joint frequency data from the Albuquerque International Airport were used for all the SNL/NM facilities. Los Alamos collection points were TA-6 and TA-41. TA-6 is on the mesa and is close to the Chemistry and Metallurgy Research Facility. TA-6 was also used to represent the meteorologic conditions from the Omega West Reactor stack, which is 45 m above the mesa top. Ground-level releases from the Omega West Reactor were modeled using meteorologic data from TA-41, which is in the same canyon as the reactor. Limitations on TA-41 data exist because data were collected only for 1.5 years. Because the topography dominates over seasonal differences, the fraction of year is not a serious complication. Of course, the longer data are averaged, the more representative they would be of any average year.

Oak Ridge Research Reactor and its hot cells are represented by meteorologic data collected at the X-10 met tower, while the data for the Power Burst Facility were collected nearby.

See Table C-7

Sandia National Laboratories/New Mexico 15 m Albuquerque International Airport Pasquill A-F
(1960-1964 Average)
(Created 16-Aug-95 LHS)

dir; wind towards this direction

SP:ST; wind speed: wind stability

wind speed categories:

- 1: 1.03 m/sec
- 2: 2.83 m/sec
- 3: 4.63 m/sec
- 4: 6.95 m/sec
- 5: 9.78 m/sec
- 6: 12.10 m/sec

Table C-7. Sandia National Laboratories/New Mexico 15 m Albuquerque International Airport (1960-1964 average)

DIR/ SP:ST	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
1 : A	0.10	0.02	0.07	0.04	0.03	0.06	0.08	0.04	0.10	0.08	0.11	0.10	0.13	0.10	0.08	0.04
1 : B	0.64	0.27	0.30	0.17	0.16	0.23	0.35	0.27	0.58	0.29	0.55	0.38	0.45	0.48	0.51	0.42
1 : C	0.17	0.08	0.06	0.05	0.04	0.08	0.15	0.10	0.19	0.08	0.11	0.07	0.10	0.08	0.11	0.10
1 : D	0.15	0.06	0.06	0.05	0.05	0.06	0.10	0.07	0.12	0.02	0.09	0.05	0.04	0.07	0.09	0.07
1 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 : F	1.36	0.77	0.99	0.64	0.72	1.35	1.78	0.99	1.17	0.38	0.53	0.42	0.42	0.53	0.57	0.66
2 : A	0.10	0.03	0.03	0.02	0.02	0.04	0.04	0.05	0.14	0.09	0.16	0.00	0.13	0.13	0.11	0.06
2 : B	0.38	0.20	0.14	0.09	0.07	0.08	0.18	0.20	0.52	0.46	0.60	0.53	0.49	0.46	0.39	0.37
2 : C	0.66	0.25	0.13	0.06	0.05	0.14	0.28	0.27	0.62	0.36	0.43	0.31	0.31	0.31	0.39	0.50
2 : D	0.50	0.19	0.19	0.06	0.12	0.21	0.30	0.23	0.37	0.18	0.25	0.17	0.17	0.16	0.22	0.27
2 : E	0.59	0.33	0.25	0.17	0.19	0.55	0.88	0.49	0.51	0.26	0.27	0.23	0.21	0.22	0.20	0.31
2 : F	2.07	1.00	0.93	0.44	0.56	1.53	2.27	1.23	0.96	0.33	0.37	0.35	0.31	0.42	0.56	0.95
3 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 : B	0.13	0.06	0.03	0.03	0.01	0.03	0.07	0.08	0.30	0.26	0.38	0.30	0.21	0.18	0.14	0.07
3 : C	0.68	0.15	0.11	0.05	0.09	0.09	0.15	0.21	0.62	0.54	0.59	0.42	0.30	0.30	0.29	0.40
3 : D	1.37	0.35	0.28	0.21	0.35	0.57	0.51	0.45	0.91	0.54	0.57	0.55	0.37	0.34	0.32	0.55
3 : E	2.18	0.82	0.30	0.18	0.26	0.54	0.59	0.39	0.55	0.32	0.30	0.24	0.19	0.25	0.36	0.62
3 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : C	0.03	0.01	0.00	0.01	0.02	0.04	0.03	0.04	0.13	0.13	0.17	0.11	0.09	0.06	0.04	0.04

Table C-7. (contd)

DIR/ SP:ST	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
4 : D	1.54	0.22	0.12	0.36	1.31	1.40	0.41	0.27	0.86	0.82	0.67	0.67	0.55	0.74	0.81	0.84
4 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : C	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.03	0.02	0.01	0.02	0.02	0.02	0.01
5 : D	0.20	0.01	0.01	0.09	0.83	0.81	0.16	0.04	0.31	0.24	0.21	0.20	0.26	0.32	0.32	0.14
5 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
6 : D	0.02	0.00	0.00	0.02	0.40	0.26	0.03	0.01	0.11	0.03	0.05	0.08	0.07	0.10	0.07	0.02
6 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	12.87	4.82	4.00	2.74	5.28	8.08	8.36	5.43	9.11	5.45	6.44	5.20	4.83	5.27	5.60	6.44

See Table C-8

TA 6 Joint frequency Pasquill (1990-1994 Average)

Created 16 Aug 1995 LHS

Applied to Chemistry and Metallurgy Research Facility and Omega West Reactor Stack Releases

dir; wind towards this direction

SP:ST; wind speed: wind stability

wind speed categories:

- 1: 0.88 m/sec
- 2: 2.50 m/sec
- 3: 4.40 m/sec
- 4: 7.00 m/sec
- 5: 10.00 m/sec
- 6: 20.00 m/sec

Table C-8. Chemistry and Metallurgy Research Facility and Omega West Reactor Stack Releases

[illegible]

Table C-8. (contd)

DIR/ SP:ST	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
4 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : D	0.02	0.08	0.01	0.00	0.00	0.00	0.00	0.03	0.13	0.27	0.19	0.37	0.88	1.01	0.27	0.02
4 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.00	0.00
4 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.10	0.17	0.02	0.00
5 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.00	0.00
6 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	3.87	3.79	3.63	3.01	3.60	3.55	3.69	6.24	8.85	8.32	7.57	7.78	10.71	11.29	9.65	4.38

See Table C-9

LANL TA41 (TA 2) - 10.5 m - Pasquill A-F (Nov 93 to Jul 95) - approx 95% recoverability

Translated to GENII format (sfs - 8/95).

Applied to Omega West Reactor ground level releases

dir; wind towards this direction

SP:ST; wind speed: wind stability

wind speed categories:

1: 0.90 m/sec

2: 2.50 m/sec

3: 4.38 m/sec

4: 7.00 m/sec

5: 10.00 m/sec

6: 15.00 m/sec

Table C-9. Omega West Reactor Ground Level Releases

[illegible]

Table C-9. (contd)

DIR/ SP:ST	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
4 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.23	0.05	0.00
4 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
5 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	2.29	1.97	2.58	2.67	6.34	7.71	4.56	1.78	0.67	0.54	0.89	2.45	51.49	6.19	3.76	4.12

See Table C-10

Oak Ridge Research Reactor - X10 Facility - 10 m Pasquill A-G (1983 to 1992 - 10 yr avg)

Translated to GENII format (sfs - 8/95).

dir; wind towards this direction

SP:ST; wind speed: wind stability

wind speed categories:

- 1: 1.79 m/sec
- 2: 2.46 m/sec
- 3: 4.47 m/sec
- 4: 6.93 m/sec
- 5: 9.61 m/sec
- 6: 13.00 m/sec

Table C-10. Oak Ridge Research Reactor - X10 Facility

[illegible]

Table C-10. (contd)

DIR/ SP:ST	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
4 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	5.44	6.09	7.92	9.90	4.85	2.22	1.49	1.41	2.11	4.62	11.04	13.38	11.42	7.75	5.38	5.02

See Table C-11

INEL-near PBF - 10 m Pasquill A-F (1987 to 1991 - 5 yr avg)

Translated to GENII format (sfs-8/95) - 90.2% of hrs recovered

dir; wind towards this direction

SP:ST; wind speed: wind stability

wind speed categories:

- 1: 1.00 m/sec
- 2: 2.50 m/sec
- 3: 4.50 m/sec
- 4: 6.93 m/sec
- 5: 13.20 m/sec
- 6: 19.00 m/sec

Table C-11. Idaho National Engineering Laboratory, Near the Power Burst Facility

DIR/ SP:ST	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
1 : A	0.42	0.47	0.42	0.38	0.27	0.24	0.21	0.22	0.28	0.37	0.37	0.31	0.30	0.30	0.32	0.43
1 : B	0.10	0.12	0.05	0.04	0.01	0.00	0.01	0.02	0.04	0.05	0.04	0.02	0.02	0.02	0.03	0.08
1 : C	0.11	0.19	0.12	0.01	0.01	0.01	0.01	0.01	0.04	0.03	0.03	0.01	0.02	0.02	0.04	0.06
1 : D	0.29	0.56	0.40	0.22	0.06	0.04	0.04	0.08	0.15	0.16	0.10	0.05	0.04	0.04	0.06	0.13
1 : E	0.26	0.34	0.44	0.31	0.11	0.05	0.04	0.15	0.18	0.18	0.13	0.06	0.05	0.06	0.06	0.12
1 : F	1.30	1.79	1.70	1.31	0.91	0.84	0.97	1.28	1.33	1.33	1.06	0.90	0.76	0.83	0.82	1.06
2 : A	0.26	0.38	0.41	0.37	0.19	0.16	0.19	0.33	0.49	0.67	0.60	0.46	0.37	0.24	0.26	0.21
2 : B	0.09	0.20	0.21	0.11	0.04	0.03	0.02	0.10	0.23	0.31	0.28	0.17	0.10	0.04	0.03	0.06
2 : C	0.15	0.41	0.40	0.09	0.01	0.01	0.03	0.08	0.16	0.23	0.19	0.11	0.04	0.02	0.02	0.03
2 : D	0.63	2.98	2.22	1.06	0.33	0.14	0.15	0.55	0.73	0.81	0.52	0.34	0.18	0.07	0.05	0.14
2 : E	0.29	0.88	1.15	1.02	0.34	0.11	0.17	0.46	0.57	0.50	0.34	0.19	0.09	0.06	0.05	0.09
2 : F	0.43	0.79	0.86	0.70	0.35	0.30	0.27	0.43	0.61	0.59	0.45	0.34	0.28	0.24	0.24	0.24
3 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 : B	0.04	0.04	0.04	0.02	0.01	0.01	0.02	0.05	0.13	0.19	0.17	0.14	0.06	0.03	0.04	0.04
3 : C	0.08	0.11	0.17	0.08	0.02	0.04	0.03	0.16	0.30	0.49	0.79	0.46	0.15	0.08	0.07	0.09
3 : D	0.43	1.62	1.36	0.45	0.08	0.05	0.23	0.73	0.94	1.34	1.78	1.17	0.33	0.11	0.07	0.16
3 : E	0.17	0.46	0.66	0.35	0.08	0.04	0.34	0.63	0.32	0.38	0.50	0.35	0.05	0.03	0.02	0.04
3 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : C	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.04	0.05	0.08	0.07	0.02	0.01	0.01	0.01
4 : D	0.70	0.71	0.51	0.16	0.01	0.01	0.08	0.32	0.74	1.29	3.46	2.03	0.30	0.08	0.08	0.25

Table C-11. (contd)

DIR/ SP:ST	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
4 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : D	0.21	0.16	0.07	0.00	0.00	0.00	0.01	0.05	0.19	0.41	2.01	1.40	0.12	0.03	0.05	0.11
5 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : D	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.62	0.37	0.03	0.01	0.00	0.02
6 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 : A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 : B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 : C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 : D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
7 : E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 : F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	5.98	12.23	11.20	6.68	2.83	2.09	2.82	5.66	7.50	9.42	13.53	8.96	3.31	2.32	2.32	3.37

C.3 Food Production Distribution Tables

Tables C-12 through C-17 give food production distributions for beef cattle and dairy cattle, by compass direction from the site and distance from the site. No tables are included for ORNL. The production figures are given in terms of head of cattle, except for INEL, where they are listed by kg/yr of meat and L/yr of milk.

These data were used outside of GENII. All the food produced in the sector being evaluated was assumed to be consumed. Spreadsheet calculations took into account the distance, direction, and total production when calculating the potential population dose.

Table C-12. Food Production Grid for SNL/NM, TA V (Annular Core Research Reactor)

Beef Cattle Total = 32355 head
distance in miles

Miles/ Sector	0-10	10-20	20-30	30-40	40-50	Total
S	173	209	332	465	563	1742
SSW	173	227	332	457	560	1749
SW	173	397	341	465	584	1960
WSW	173	522	338	465	597	2095
W	45	507	869	668	597	2686
WNW	0	387	807	699	560	2453
NW	0	87	276	371	477	1211
NNW	0	158	265	371	477	1271
N	99	232	265	371	477	1444
NNE	99	242	265	758	1137	2501
NE	99	408	367	611	788	2273
ENE	144	470	438	614	789	2455
E	173	408	404	560	713	2258
ESE	173	478	495	495	636	2277
SE	173	424	362	495	636	2090
SSE	173	233	353	495	636	1890

Table C-13. Food Production Grid for SNL/NM, TA V (Annular Core Research Reactor)

Dairy Cattle Total = 7288 head
distance in miles

Miles/ Sector	0-10	10-20	20-30	30-40	40-50	Total
S	89	45	64	82	56	336
SSW	89	58	64	76	51	338
SW	89	179	70	89	92	519
WSW	89	267	65	89	115	625
W	23	259	444	233	115	1074
WNW	198	403	278	95	0	974
NW	0	35	52	63	81	231
NNW	0	42	45	63	81	231
N	50	75	45	63	81	314
NNE	50	82	45	331	367	875
NE	50	191	23	11	14	289
ENE	73	214	8	11	14	320
E	89	161	6	8	8	272
ESE	89	229	124	4	5	451
SE	89	184	11	4	5	293
SSE	89	42	4	4	7	146

Table C-14. Food Production Grid for LANL, Centered on TA-53

Beef Cattle Total = 28900 head
distance in kilometers

km/ Sector	0-1	1-2	2-4	4-8	8-15	15-20	20-30	30-40	40-60	60-80	Total
S	0	0	0	0	21	73	290	391	414	533	1722
SSW	0	0	0	0	0	9	258	258	295	639	1459
SW	0	0	0	0	21	68	78	209	391	113	880
WSW	0	0	0	0	16	73	197	253	652	448	1639
W	0	0	0	0	34	97	289	294	594	781	2089
WNW	0	0	0	0	17	103	290	289	786	2392	3877
NW	0	0	10	0	6	57	167	179	511	895	1825
NNW	0	0	10	0	12	50	193	62	610	1255	2192
N	0	0	0	0	14	46	121	206	772	1020	2179
NNE	0	0	0	0	13	5	32	256	701	878	1885
NE	0	0	0	1	10	19	5	129	234	1350	1748
ENE	0	0	0	6	36	30	146	53	614	1348	2233
E	0	0	0	7	31	30	149	70	251	466	1004
ESE	0	0	0	0	0	0	134	14	146	465	759
SE	0	0	0	0	55	51	33	0	467	826	1432
SSE	0	0	0	0	47	79	132	233	613	873	1977

Table C-15. Food Production Grid for LANL, Centered on TA-53

Dairy Cattle Total = 1963 head
distance in kilometers

km/ Sector	0-1	1-2	2-4	4-8	8-15	15-20	20-30	30-40	40-60	60-80	Total
S	0	0	0	0	0	0	0	0	0	0	0
SSW	0	0	0	0	0	0	0	0	0	1800	1800
SW	0	0	0	0	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0	0	0	0
N	0	0	0	0	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0	0	0
ENE	0	0	0	0	0	9	24	0	0	0	33
E	0	0	0	0	0	21	109	0	0	0	130
ESE	0	0	0	0	0	0	0	0	0	0	0
SE	0	0	0	0	0	0	0	0	0	0	0
SSE	0	0	0	0	0	0	0	0	0	0	0

Table C-16. INEL PBF Food Production Grid (from FOODPROD.ID provided by INEL for NPR EIS)

INEL GENII Food Production Grid (meat, milk)

Updated 15-May-90 PRL, Data taken from file COWVEG1.DAT

Beef Cattle Production - kg/y meat Total = 26748000
distance in meters

Meters/ Sector	800	2400	4000	5600	7200	8000	24000	40000	56000	72000	Total
S	0	0	0	0	0	0	0	0	0	1710000	1710000
SSW	0	0	0	0	0	0	0	0	0	0	0
SW	0	0	0	0	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0	0	0	0	0
W	0	0	0	0	0	0	533000	533000	0	0	1066000
WNW	0	0	0	0	0	0	341000	793000	1100000	0	2234000
NW	0	0	0	0	0	0	0	394000	2160000	541000	3095000
NNW	0	0	0	0	0	0	0	252000	252000	63800	567800
N	0	0	0	0	0	0	755000	0	139000	0	894000
NNE	0	0	0	0	0	0	0	0	411000	1470000	1881000
NE	0	0	0	0	0	0	0	164000	1470000	749000	2383000
ENE	0	0	0	0	0	0	0	0	519000	1210000	1729000
E	0	0	0	0	0	0	0	83200	1200000	2410000	3693200
ESE	0	0	0	0	0	0	0	0	0	1970000	1970000
SE	0	0	0	0	0	0	0	0	2830000	705000	3535000
SSE	0	0	0	0	0	0	0	0	1530000	460000	1990000

Table C-17. INEL PBF Food Production Grid (from FOODPROD.ID provided by INEL for NPR EIS)

INEL GENII Food Production Grid (meat, milk)

Updated 15-May-90 PRL, Data taken from file COWVEG1.DAT

Dairy Cattle Production -L/y milk
distance in meters

Meters/ Sector	800	2400	4000	5600	7200	8000	24000	40000	56000	72000	Total
S	0	0	0	0	0	0	0	0	0	5700000	5700000
SSW	0	0	0	0	0	0	0	0	0	0	0
SW	0	0	0	0	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0	0	0	0	0
W	0	0	0	0	0	0	562000	562000	0	0	1124000
WNW	0	0	0	0	0	0	361000	843000	0	0	1204000
NW	0	0	0	0	0	0	0	402000	0	0	402000
NNW	0	0	0	0	0	0	803000	0	0	0	803000
N	0	0	0	0	0	0	803000	0	0	0	803000
NNE	0	0	0	0	0	0	0	0	1120000	0	1120000
NE	0	0	0	0	0	0	0	482000	4140000	0	4622000
ENE	0	0	0	0	0	0	0	0	1490000	3410000	4900000
E	0	0	0	0	0	0	0	0	3730000	6990000	10720000
ESE	0	0	0	0	0	0	0	0	0	69900000	69900000
SE	0	0	0	0	0	0	0	0	10200000	2570000	12770000
SSE	0	0	0	0	0	0	0	0	5540000	1570000	7110000

Appendix D

Climate and Meteorology



Appendix D

Climate and Meteorology

D.1 Sandia National Laboratories/New Mexico

The Sandia National Laboratories/New Mexico (SNL/NM) is located near the boundary between a mid-latitude semiarid and a tropical semiarid climate (Critchfield 1974). Meteorological data are available from measurements at the Albuquerque International Airport and at the adjacent Kirtland Air Force Base. Climatic averages for a number of meteorological parameters are provided in Table D-1. On an average, the maximum daily temperature exceeds 32°C (90°F) on 64 days per year and is below 0°C (32°F) on 5 days per year; the minimum daily temperature is below 0°C (32°F) on 120 days per year and is below -18°C (0°F) about once every two years (DOC 1987a). July is the warmest month, with daily maximum and minimum temperatures averaging 34°C (93°F) and 18°C (65°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 8°C (47°F) and -5°C (22°F), respectively (DOC 1987a).

Annual precipitation is on the order of 21 cm (8 in.) with about 55% falling from July through October. Precipitation is about double in the Manzano Mountains to the east (McCord et al. 1993). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 60 days per year and the area experiences an average of 42 thunderstorm days per year. The average annual snowfall is 28 cm (11 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 4 days per year (DOC 1987a).

Winds across the SNL/NM are modified by the Manzano Mountains and other terrain features. The prevailing wind direction at the Albuquerque International Airport is from the southeast. Wind speeds average about 4 m/s (9 mph) at about 7 m (23 ft) above ground level. Average wind speeds are highest in April (5 m/s [11 mph]) and lowest in December (3.5 m/s [8 mph]) (DOC 1987a). Figure D-1 provides the average distribution of the direction from which the wind blows and wind speeds at the proposed project location.

D.2 Los Alamos National Laboratory

The Los Alamos National Laboratory (LANL) has a semiarid, temperate mountain climate (Bowen 1990). Meteorological data are available from onsite measurements, with the main monitoring site located in the TA-59 area (on a mesa). Climatic averages for a number of meteorological parameters are provided.

Table D-1. Sandia National Laboratories/New Mexico (SNL/NM) Average Local Climatology^(a)

Station Name: Albuquerque International Airport
Elevation: 1619 m

Monthly Averages							
Month	Temp. (°F)	Precip. (Inches)	Wind Speed (MPH)	Cloud Cover (10ths)	Precip. Days (#)	Daily Relative Humidity	
						Max (%)	Min (%)
Jan	35	0.4	8.0	4.8	3.9	71	40
Feb	39	0.4	8.8	4.9	4.1	65	32
Mar	46	0.5	10.1	5.1	4.6	56	24
Apr	55	0.4	11.0	4.6	3.3	49	18
May	64	0.5	10.5	4.2	4.3	48	18
Jun	75	0.5	10.0	3.3	3.8	46	17
Jul	79	1.3	9.1	4.5	8.9	60	27
Aug	76	1.5	8.2	4.3	9.2	66	30
Sep	69	0.9	8.6	3.6	5.7	62	31
Oct	57	0.9	8.3	3.5	4.9	62	30
Nov	44	0.4	7.9	4.0	3.5	66	36
Dec	36	0.5	7.7	4.6	4.1	71	43
Annual Mean Air Temp:		56.2°F					
Anemometer Height:		7.0 m					
Mean Annual Wind Speed:		9 mph					
Annual Precipitation:		8.1 in.					
Precipitation Days:		60 yr ⁻¹					
Thunderstorms Freq:		42 yr ⁻¹					
(a) Meteorological parameters are presented using the units with which they are routinely measured (for example, temperature: °F; wind speed: mph). Data are from measurements made at Albuquerque International Airport (DOC 1987a).							

in Table D-2. On average, the maximum daily temperature exceeds 32°C (90°F) on 2 days per year and is below 0°C (32°F) on 19 days per year; the minimum daily temperature is below 0°C (32°F) on 154 days per year and is below -18°C (0°F) on 2 days per year (Bowen 1990). July is the warmest month, with daily maximum and minimum temperatures averaging 27°C (81°F) and 13°C (55°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 4°C (40°F) and -8°C (17°F), respectively (Bowen 1990). Significant temperature differences will frequently occur between the mesa tops and canyons within LANL, with cooler temperatures in the canyons.

Annual precipitation is on the order of 46 cm (18 in.) with about 40% falling in July and August. Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 89 days

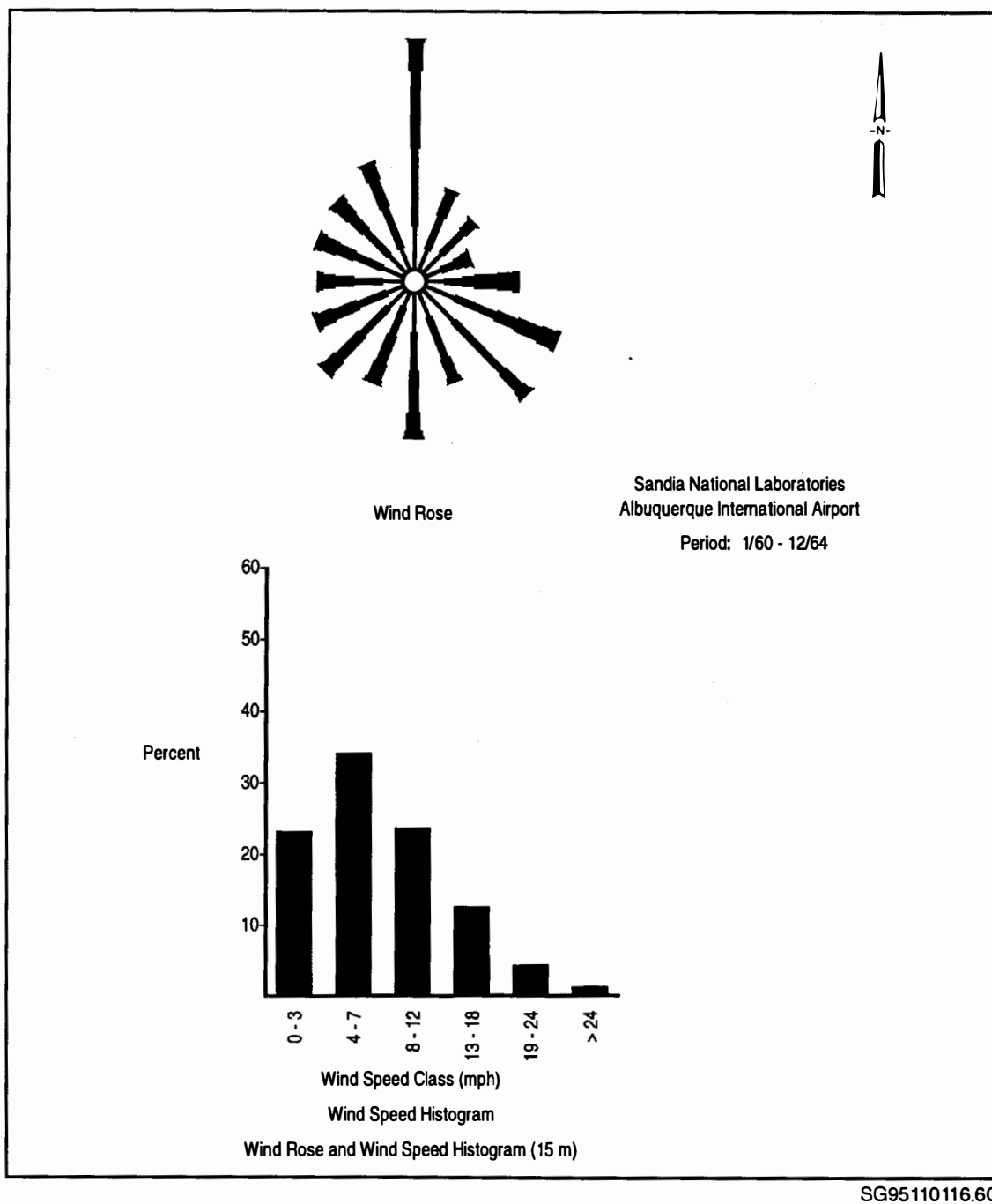


Figure D-1. Average Distribution of Wind Directions and Wind Speeds at Albuquerque International Airport

Table D-2. Los Alamos National Laboratory (LANL) Average Local Climatology^(a)**Station Name: Los Alamos National Laboratory****Elevation: 2260 m**

Monthly Averages							
Month	Temp. (°F)	Precip. (Inches)	Wind Speed (MPH)	Cloud Cover (10ths)	Precip. Days (#)	Daily RH	
						Max (%)	Min (%)
Feb	32	0.7	5.5	4.9	6.0	75	37
Mar	38	1.0	7.1	5.1	7.0	70	34
Apr	46	0.9	8.0	4.6	5.5	60	26
May	55	1.1	7.8	4.2	6.9	62	24
Jun	65	1.1	7.3	3.3	6.0	58	22
Jul	68	3.2	6.0	4.5	14.4	69	30
Aug	66	3.9	5.7	4.3	14.5	77	35
Sep	60	1.6	6.3	3.6	7.9	72	32
Oct	50	1.5	6.2	3.5	5.5	70	34
Nov	38	1.0	5.9	4.0	4.3	70	36
Dec	31	1.0	5.0	4.6	5.1	72	40
Annual Mean Air Temp: 48.1 °F Anemometer Height: 12.0 m Mean Annual Wind Speed: 6 mph Annual Precipitation: 17.8 in Precipitation Days: 89 yr ⁻¹ Thunderstorms Freq: 58 yr ⁻¹							
(a) Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made onsite (Bowen et al. 1990). Cloud cover data are from Albuquerque, New Mexico (DOC 1987b).							

per year and the area experiences an average of 58 thunderstorm days per year. The average annual snowfall is 130 cm (52 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 14 days per year (Bowen 1990).

Throughout the year, surface winds are strongly influenced by local and regional complex terrain. Mountain-valley circulation patterns often produce significant diurnal variations in the winds. As a result, wind directions and speeds may vary significantly from location to location on the Pajarito Plateau (Bowen 1990). The prevailing wind direction in the western portion of LANL is from the west-northwest; while in

the eastern portion of the installation, it is from the southwest. Over the course of a year, wind speeds average about 3 m/s (6 mph) at about 12 m (39 ft) above ground level. Average wind speeds are highest in March (3.6 m/s [8 mph]) and lowest in January and December (2.2 m/s [5 mph]) (Bowen 1990). Figures D-2 and D-3 provide the average distribution of the direction from which the wind blows and wind speeds at the proposed project location.

D.3 Oak Ridge National Laboratory

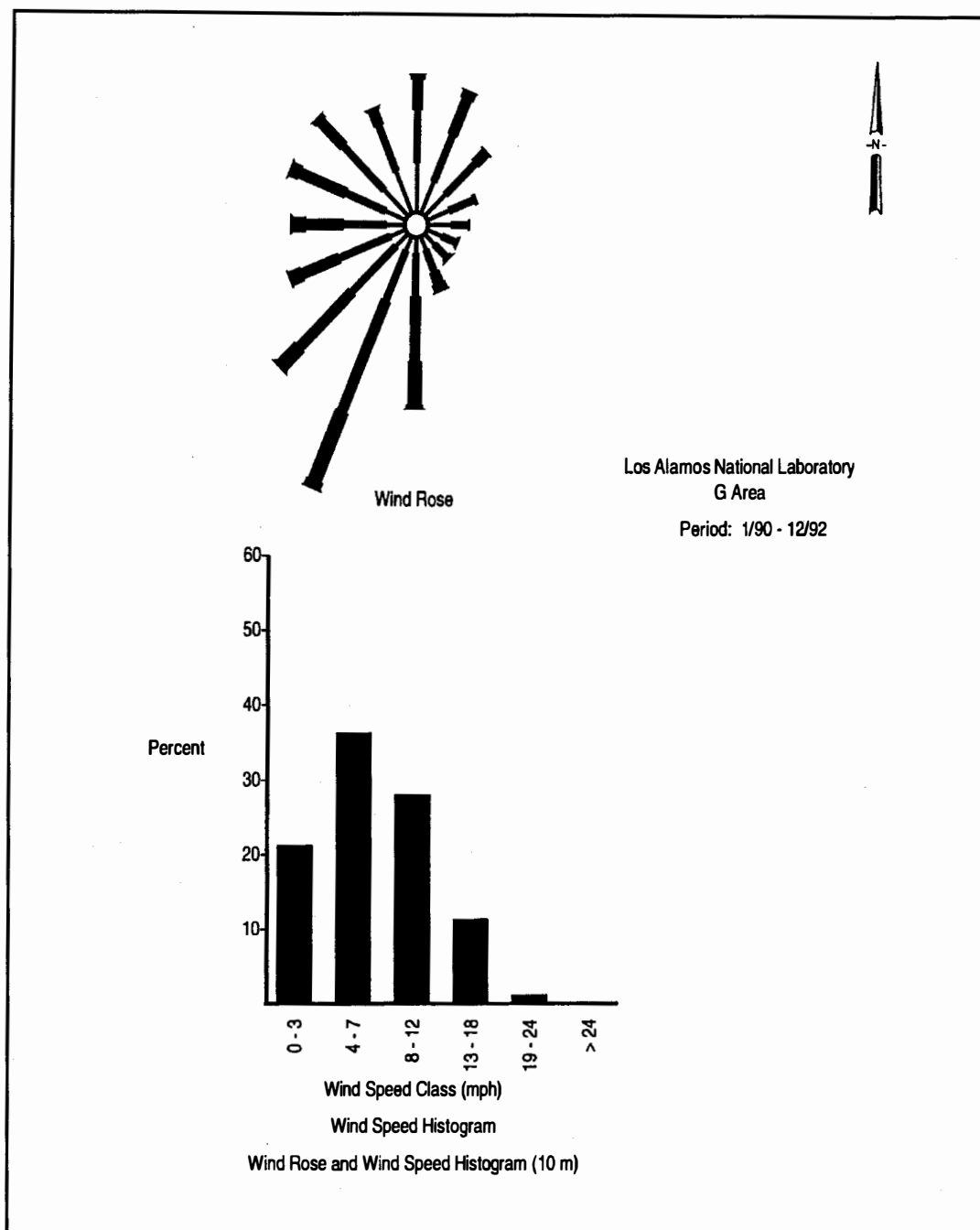
The Oak Ridge National Laboratory (ORNL) is located near the boundary between a humid subtropic and a humid continental warm summer climate (Critchfield 1974). Meteorological data are available from onsite measurements and from measurements in the city of Oak Ridge, Tennessee. Climatic averages for a number of meteorological parameters are provided in Table D-3. On an average, the maximum daily temperature exceeds 32°C (90°F) on 30 days per year and is below 0°C (32°F) on 6 days per year; the minimum daily temperature is below 0°C (32°F) on 87 days per year and is below -18°C (0°F) about once every two years (DOC 1987a). July is the warmest month, with daily maximum and minimum temperatures averaging 31°C (87°F) and 19°C (66°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 8°C (46°F) and -2°C (28°F), respectively (DOC 1987a).

Annual precipitation is on the order of 140 cm (55 in.). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 128 days per year and the area experiences an average of 51 thunderstorm days per year. The average annual snowfall is 33 cm (13 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of four days per year (DOC 1987a).

Winds on the ORNL are influenced by the local topography. Mountain ridges and valleys tend to channel winds and mountain valley circulation often produces significant diurnal variations in the winds. As a result, wind directions and speeds may vary significantly from location to location across the ORNL. The prevailing wind direction in the ORNL's northeast-trending valleys and in the city of Oak Ridge is from the southwest. A high incidence of winds is also experienced from neighboring sectors and in the opposite direction. Wind speeds in the city of Oak Ridge average about 2 m/s (4 mph) at about 9 m (30 ft) above ground level (DOC 1987a). Average wind speeds are highest in April (2.5 m/s [6 mph]) and lowest in October (1.5 m/s [3.5 mph]) (DOC 1987a). Figure D-4 provides the average distribution of the direction from which the wind blows and wind speeds at the proposed project location.

D.4 Idaho National Engineering Laboratory

The Idaho National Engineering Laboratory (INEL) has a mid-latitude semiarid climate (Clawson et al. 1989). Meteorological data are available from onsite measurements at the Central Facilities Area Meteorology Station and other onsite monitoring locations (Clawson et al. 1989). Climatic averages for a number of meteorological parameters are provided in Table D-4. On an average, the maximum daily temperature exceeds 32°C (90°F) on 25 days per year and is below 0°C (32°F) on 60 days per year; the



SG95110116.57

Figure D-2. Average Distribution of Wind Directions and Wind Speeds at Los Alamos National Laboratory (G Area)

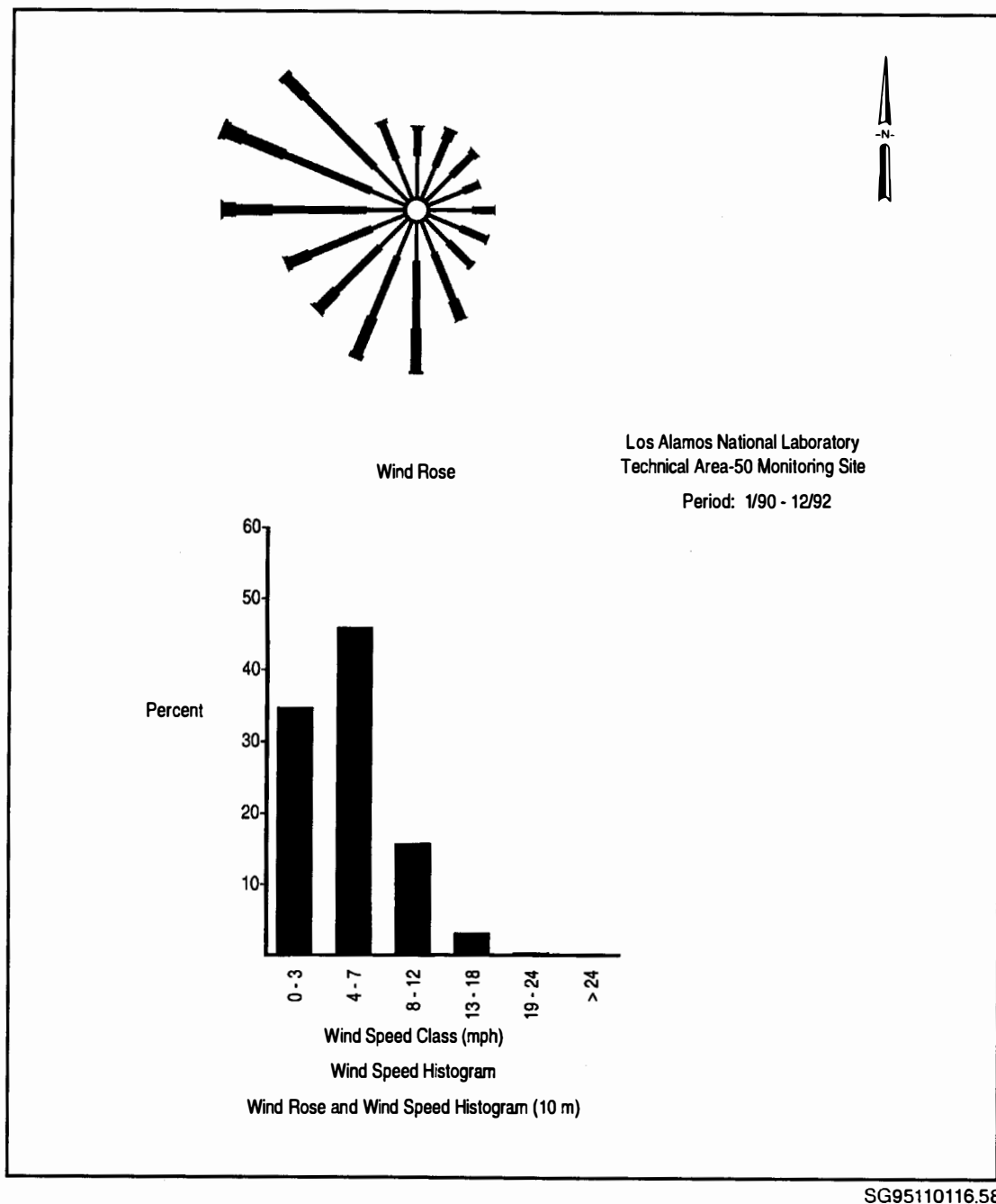
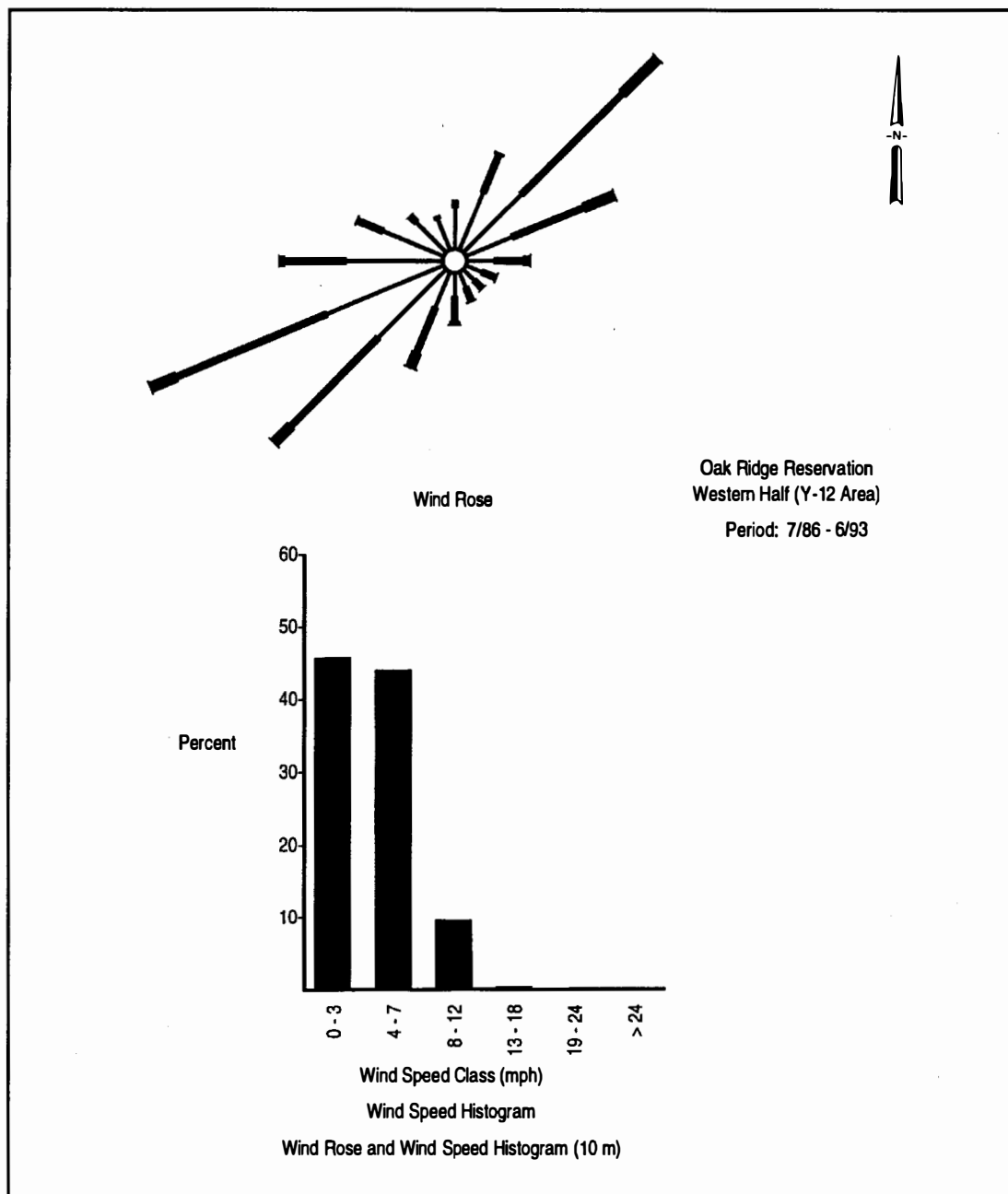


Figure D-3. Average Distribution of Wind Directions and Wind Speeds at Los Alamos National Laboratory (Technical Area-50 monitoring site)

Table D-3. Oak Ridge National Laboratory (ORNL) Average Local Climatology^(a)**Station Name: Oak Ridge, Tennessee****Elevation: 268 m****MT2 Monitoring Site at X-10 facility****Elevation: 289 m**

Monthly Averages							
Month	Temp. (°F)	Precip. (Inches)	Wind Speed (MPH)	Cloud Cover (10ths)	Precip. Days (#)	Daily RH	
						Max (%)	Min (%)
Feb	42	4.6	4.0	6.5	11.4	73	48
Mar	50	6.2	4.3	6.5	12.6	68	47
Apr	58	4.4	4.3	5.9	10.8	72	47
May	65	4.2	3.8	5.9	10.7	76	52
Jun	73	4.3	3.3	5.5	10.3	77	53
Jul	77	5.2	3.1	5.8	11.9	74	50
Aug	75	3.8	2.9	5.5	10.4	81	55
Sep	69	3.8	2.9	5.6	8.3	77	56
Oct	57	2.9	3.0	5.0	7.9	71	47
Nov	48	4.5	3.4	6.1	10.1	71	48
Dec	39	5.7	3.5	6.5	10.9	72	55
Annual Mean Air Temp: 57.4°F (Oak Ridge)							
Anemometer Height: 10.0 m (MT2/X-10)							
Mean Annual Wind Speed: 4 mph (MT2/X-10)							
Annual Precipitation: 54.8 in (Oak Ridge)							
Precipitation Days: 128 yr ⁻¹ (Oak Ridge)							
Thunderstorms Freq: 51 yr ⁻¹ (Oak Ridge)							
(a) Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at the X-10 meteorological tower and in the city of Oak Ridge, Tennessee. Temperature, wind speed, and humidity data are from the MT2/X-10 monitoring location (data were provided by meteorologist Ron Sharp [ORNL Office of Environmental Compliance and Documentation] using Oak Ridge Meteorological Data Analysis Program. The program reads archived hourly meteorological data and generates tables of climatological averages, input files for atmospheric dispersion models, and other meteorological support products). Other meteorological data are from monitoring in the city of Oak Ridge (DOC 1987a).							



SG95110116.59

Figure D-4. Average Distribution of Wind Directions and Wind Speeds at Oak Ridge National Laboratory

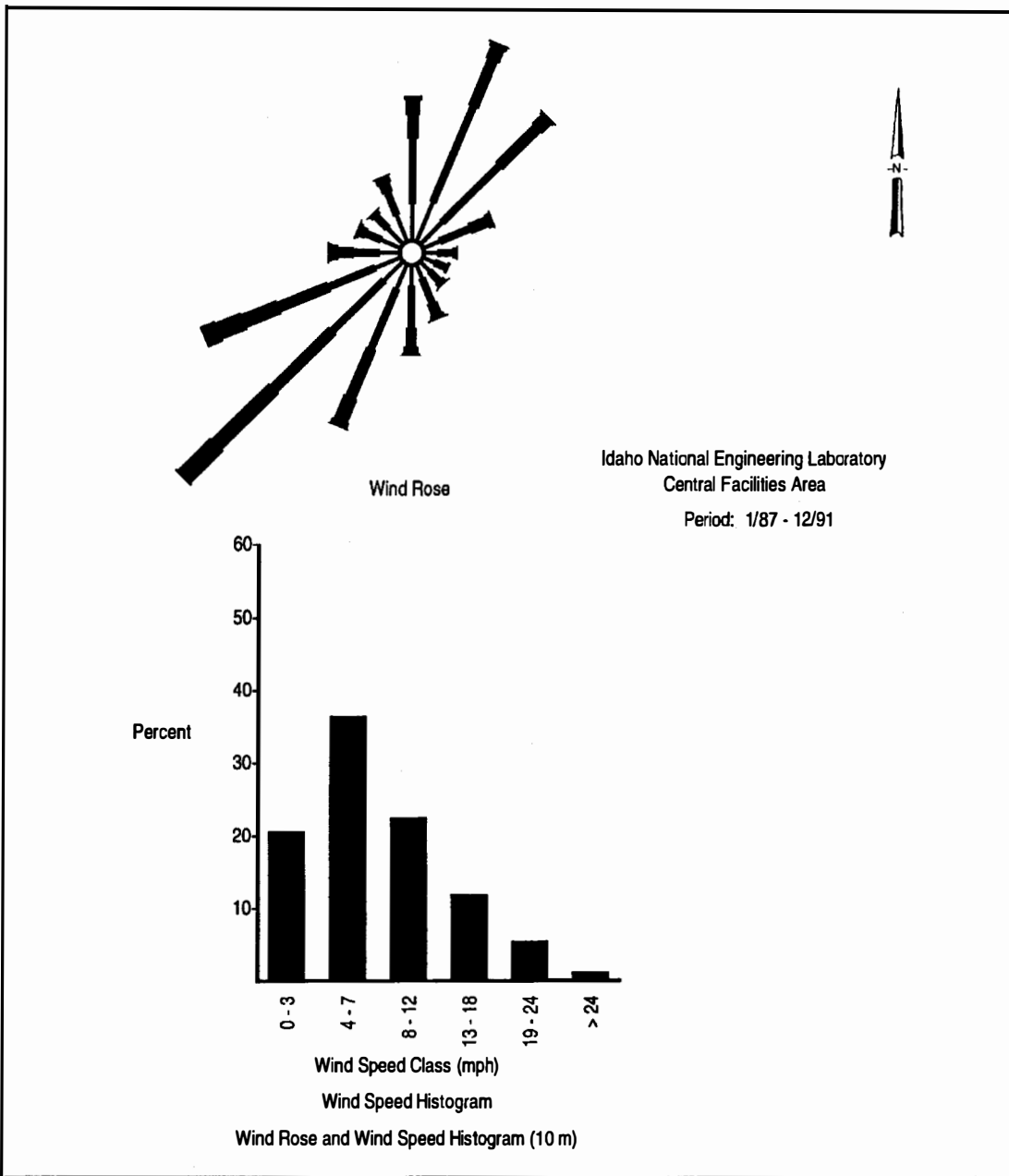
Table D-4. Idaho National Engineering Laboratory (INEL) Average Local Climatology^(a)**Station Name: INEL - Central Facilities Area****Elevation: 1530 m**

Monthly Averages							
Month	Temp. (°F)	Precip. (Inches)	Wind Speed (MPH)	Cloud Cover (10ths)	Precip. Days (#)	Daily RH	
						Max (%)	Min (%)
Feb	22	0.6	6.9	7.6	5.9	89	42
Mar	31	0.6	8.7	7.1	6.2	84	34
Apr	42	0.7	9.3	6.7	6.0	81	23
May	51	1.2	9.3	6.2	7.8	83	22
Jun	60	1.2	8.9	5.0	6.9	73	16
Jul	68	0.5	8.0	3.4	3.7	59	16
Aug	66	0.6	7.7	3.8	3.7	65	15
Sep	56	0.6	7.2	4.0	3.6	74	18
Oct	44	0.5	6.8	5.1	3.7	82	24
Nov	30	0.7	6.4	7.2	5.7	86	30
Dec	19	0.8	5.1	7.9	7.1	89	40
Annual Mean Air Temp:			42.0°F				
Anemometer Height:			6.1 m				
Mean Annual Wind Speed:			8 mph				
Annual Precipitation:			8.7 in				
Precipitation Days:			69 yr ⁻¹				
Thunderstorms Freq:			23 yr ⁻¹				
(a) Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made onsite at the Central Facilities Area (Clawson et al. 1989). Cloud cover data are from Pocatello, Idaho (DOC 1987c).							

minimum daily temperature is below 0°C (32°F) on 214 days per year and is below -18°C (0°F) on 34 days per year (Clawson et al. 1989). July is the warmest month, with daily maximum and minimum temperatures averaging 31°C (87°F) and 9°C (49°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging -3°C (27°F) and -15°C (5°F), respectively (Clawson et al. 1989).

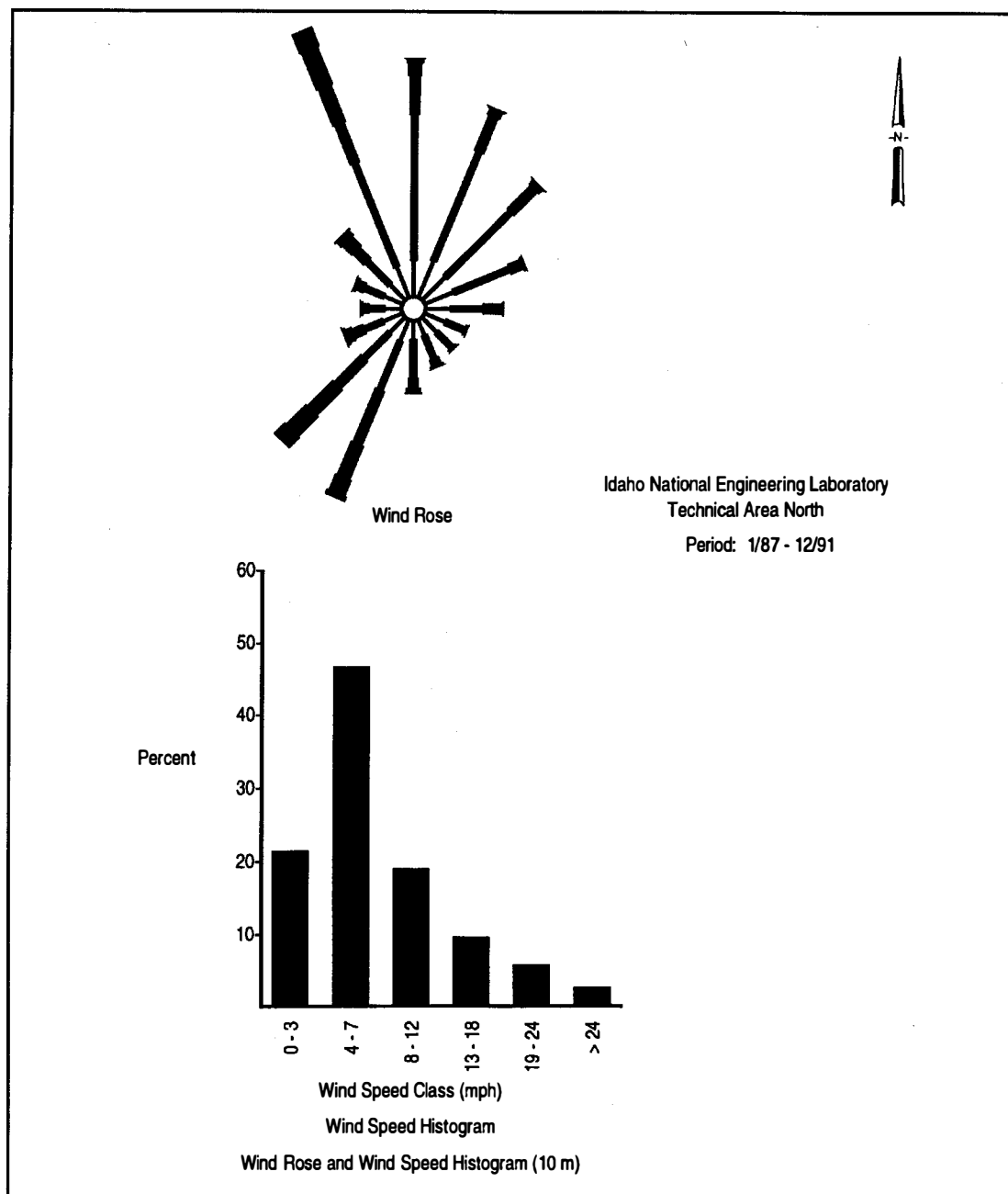
Annual precipitation is on the order of 22 cm (9 in.) with about 27% falling in May and June. Measurable precipitation (defined as 0.01 in. or greater) is recorded on an average of 69 days per year and the area experiences an average of 23 thunderstorm days per year. Daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 10 days per year; the average annual snowfall is 70 cm (28 in.) (Clawson et al. 1989).

Winds at the INEL are strongly influenced by the orientation of the bordering mountain ranges and the general orientation of the Eastern Snake River Plain. Local mountain-valley circulations, both nighttime drainage winds and upslope flows, are commonly observed across the installation. As a result of such local influences, significant variations in wind direction and speed are often observed across the installation. The prevailing wind direction in the Central Facilities Area (in the southwestern portion of the installation) is from the west-southwest. In the Technical Area North (in the northern portion of the installation), the prevailing wind direction is from the north. Wind speeds at the Central Facilities Area and Technical Area North average 3.4 m/s (7.5 mph) and 3.1 m/s (7.1 mph), respectively, at 6 m (20 ft) above ground level (Clawson et al. 1989). Average wind speeds at both monitoring locations are highest in April (4 m/s [9 mph]) and lowest in December (2 m/s [5 mph]) (Clawson et al. 1989). Figures D-5 and D-6 provide the average distribution of the direction from which the wind blows and wind speeds at the proposed project location.



SG95110116.55

Figure D-5. Average Distribution of Wind Directions and Wind Speeds at Idaho National Engineering Laboratory (Central Facilities Area)



SG95110116.56

Figure D-6. Average Distribution of Wind Directions and Wind Speeds at Idaho National Engineering Laboratory (Technical Area North)

